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REPORT OF

THE CHICAGO ASSOCIATION OF COMMERCE COMMITTEE OF INVESTIGATION ON SMOKE ABATEMENT AND ELECTRIFICATION OF RAILWAY TERMINALS

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SMOKE ABATEMENT

AND

ELECTRIFICATION OF RAILWAY TERMINALS

IN CHICAGO

REPORT OF

THE CHICAGO ASSOCIATION OF COMMERCE
COMMITTEE OF INVESTIGATION ON SMOKE ABATEMENT
AND ELECTRIFICATION OF RAILWAY TERMINALS

W. F. M. GOSS, CHIEF ENGINEER

CHICAGO
1915

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Mr. Defrees, as President of The Chicago Association of Commerce in 1914, served during that year as an ex officio member of the Committee. After this service he was elected to membership, January 8, 1915, to fill the vacancy caused by the resignation of Mr. Elting.

Mr. Dering, as President of The Chicago Association of Commerce in 1915, served during that year as an ex officio member of the Committee.

Mr. Elting, as President of The Chicago Association of Commerce, was ex officio a member of the Committee for the calendar year 1913. After this service he was elected a member, May 29, 1914, to fill the vacancy caused by the resignation of Mr. Rawson. Mr. Elting resigned January 8, 1915.

Mr. Holden was elected September, 1914, to fill the vacancy caused by the death of Mr. Miller.

Mr. Kimbark, as President of The Chicago Association of Commerce in 1912, served during that year as an ex officio member of the Committee.

Mr. Miller was one of the original members of the Committee and served until the day of his death, August 23, 1914.

Mr. Rawson, one of the original members of the Committee, resigned his membership May 26, 1914.

Mr. Schaff, one of the original members of the Committee, resigned his membership May 31, 1912.

Mr. Starring, one of the original members of the Committee, resigned his membership December 30, 1911.

Mr. Wheeler, as President of The Chicago Association of Commerce in 1911, was, during that year, an ex officio member of the Committee. After this service he was elected to membership, January 26, 1912, to fill the vacancy caused by Mr. Starring's resignation.

Mr. Davis was appointed Secretary to the Committee, May 28, 1914.

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HUGH PATTISON, Electrical Engineer

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A. H. TRACY, Assistant Electrical Engineer

Formerly Engineer, British Westinghouse Electric & Manufacturing Company, and later Assistant Engineer in Charge of Power House, Transmission, Substation, Distribution and Motive Power Equipment Calculations for the West Jersey & Seashore Railroad, Long Island Railroad and Pennsylvania Railroad; also Assistant Engineer, Construction Department, Pennsylvania Tunnel & Terminal Railroad.

B. HOFFMAN, Assistant Mechanical Engineer

Formerly Assistant Engineer of Tests, Atchison, Topeka & Santa Fe Railway.

H. E. BARTLETT, Assistant Terminal Engineer

Formerly Chief Draftsman, Construction Department, Missouri Pacific Railway, and later Engineer of Terminals, Chicago Passenger Subways.

JAMES WALKER, Assistant Engineer

Consulting Engineer, Chicago. Formerly Chief Engineer, Metropolitan West Side Elevated Railway Company, Chicago.

C. S. SALE, Editor‡

General Manager, Engineering Publishing Co., Indianapolis, Ind.

ERNST C. MEYER, Statistician

Formerly with U. S. Bureau of Census, Tariff Board, President Taft's Economy and Efficiency Commission. Later Director of Surveys and Exhibits, Rockefeller Foundation International Health Commission.

NORMAN H. DAVIS, Secretary

Formerly Auditor Missouri Southern Railroad, and Director Laclede Land & Improvement Company.

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* Died May 19, 1913.

† From June 27, 1913, to the completion of the work.

‡ Succeeded Benj. C. Burt, 1913.

LETTER OF TRANSMITTAL

COMMITTEE OF INVESTIGATION ON
SMOKE ABATEMENT AND ELECTRIFICATION OF
RAILWAY TERMINALS

Office of the Committee,
Chicago, November 22, 1915

MR. CHARLES L. DERING, President,
The Chicago Association of Commerce:

SIR:

Your Committee of Investigation on Smoke Abatement and Electrification of Railway Terminals in Chicago has the honor of herewith presenting its final report.

Since its appointment in March, 1911, your committee has given close attention to the subject in hand and has had the benefit of the advice and researches of an able staff of experts.

Having had at its command ample resources and the advice and assistance of such expert counsel as it chose to employ, the committee feels justified in hoping that its report will be of some value in the solution of a difficult civic problem not only in Chicago but elsewhere.

The committee has had no difficulty in obtaining the necessary data from the railroads directly interested and is under many obligations to them and to other organizations and individuals in this country and abroad for valuable assistance and advice.

While the committee's labors have consumed over four years in time, it feels that the importance of the subject matter of the investigation and the effect in our own city, and in other terminal cities, required it to proceed cautiously and to form conclusions only after thorough investigation and careful consideration.

By Order of the Committee,

JESSE HOLDOM, Chairman

CONTENTS

INTRODUCTION

THE CITY OF CHICAGO

PART I

THE NECESSITY FOR THE ELECTRIFICATION OF CHICAGO'S RAILROAD TERMINALS

101. SMOKE ABATEMENT IN LARGE CITIES, DOMESTIC AND FOREIGN

THE LITERATURE OF SMOKE ABATEMENT

METHODS AND REGULATIONS EMPLOYED IN SMOKE ABATEMENT

PHYSICAL, MECHANICAL AND CHEMICAL MEANS OF ABATING SMOKE

EFFECTS OF SMOKE UPON HEALTH

EFFECTS OF SMOKE UPON VEGETATION

LOSS AND DAMAGE TO PROPERTY

102. SMOKE ABATEMENT IN CHICAGO

103. THE TERRITORY EMBRACED BY THE COMMITTEE'S INVESTIGATION

104. COAL AND COKE CONSUMPTION

COAL AND COKE DELIVERED AND CONSUMED

THE ORIGIN OF FUEL CONSUMED

FUEL CONSUMPTION BY SERVICES

AMOUNT OF COAL AND COKE CONSUMED IN DIFFERENT DISTRICTS WITHIN THE AREA OF INVESTIGATION

105. SMOKE

PROPERTIES OF SMOKE

VISIBLE PROPERTIES OF SMOKE

Conditions Promoting Visible Smoke

Solid Constituents of Smoke

Incidental Facts Concerning Solids in Smoke

Gaseous Constituents of Smoke

Incidental Facts Concerning the Gaseous Products of Combustion

Conclusions

106. THE RELATIVE IMPORTANCE OF THE STEAM LOCOMOTIVE AS A SOURCE OF SMOKE

107. THE RELATIVE IMPORTANCE OF STEAM VESSELS AS A SOURCE OF SMOKE

108. THE RELATIVE IMPORTANCE OF HIGH PRESSURE STEAM STATIONARY POWER AND HEATING PLANTS AS A SOURCE OF SMOKE

109. THE RELATIVE IMPORTANCE OF LOW PRESSURE STEAM AND OTHER STATIONARY HEATING PLANTS AS A SOURCE OF SMOKE

110. THE RELATIVE IMPORTANCE OF METALLURGICAL AND MANUFACTURING PLANTS AS A SOURCE OF SMOKE

111. SMOKE FROM OIL FUELS

112. ALLIES OF SMOKE IN ATMOSPHERIC POLLUTION

Primary Sources of Atmospheric Dust

Secondary Sources of Atmospheric Dust

Conclusions

113. ATMOSPHERIC POLLUTION AS DISCLOSED BY THE STUDY OF THE ATMOSPHERE

A Study of Meteorological Conditions in their Relation to Atmospheric Pollution

The Atmosphere of Cities as Described in Scientific Literature

Composition of the Atmosphere of Chicago as Disclosed by Analyses of Air Samples

114. CONCLUSIONS AS TO THE NECESSITY FOR THE ELECTRIFICATION OF CHICAGO'S RAILROAD TERMINALS AS A MEANS IN SMOKE ABATEMENT

115. CHICAGO'S PROBLEM IN SMOKE ABATEMENT AS DISCLOSED BY THE RESEARCHES OF THE COMMITTEE

PART II

TECHNICAL FEASIBILITY AND COST OF ELECTRIFYING THE RAILROAD TERMINALS OF CHICAGO

201. THE RAILROAD TERMINALS OF CHICAGO

202. STATISTICS OF OPERATION, TRAFFIC AND TRAIN MOVEMENTS

203. GROWTH OF THE CHICAGO RAILROAD TERMINALS

204. THE POSSIBILITY OF ELIMINATING THE STEAM LOCOMOTIVE AND OF MEETING ALL OPERATING REQUIREMENTS WITHOUT RESORT TO COMPLETE ELECTRIFICATION

American Railroad Electrifications

English Railroad Electrifications

French Railroad Electrifications

German Railroad Electrifications

Swiss Railroad Electrifications

Italian Railroad Electrifications

Austrian Railroad Electrifications

Hollandish Railroad Electrifications

Norwegian and Swedish Railroad Electrifications

Australian Railroad Electrifications

206. A COMPARATIVE STUDY OF COMPLETED STEAM RAILROAD ELECTRIFICATION PROJECTS

207. EXISTING ELECTRIC TRACTION SYSTEMS

Power Stations

Transmission Systems

Substations

CONTACT SYSTEMS

ELECTRIC LOCOMOTIVES AND MOTOR CARS

208. TECHNICAL FEASIBILITY OF THE ELECTRIFICATION OF THE CHICAGO RAILROAD TERMINALS

209. THE EXTENT OF THE PLAN UNDERLYING ESTIMATES OF THE COST OF ELECTRIFYING CHICAGO'S RAILROAD TERMINALS

FACTORS CONSIDERED IN FIXING THE LIMITS OF ELECTRIFICATION

EXTENT OF THE PLAN OF ELECTRIFICATION BY RAILROADS

210. SYSTEMS SELECTED AS A BASIS FOR ESTIMATES OF COST

211. ENERGY REQUIREMENTS

212. GENERAL CONSIDERATIONS UNDERLYING ESTIMATES OF COST

213. THE ESTIMATED COST OF COMPLETE ELECTRIFICATION

The Direct Cost of Electrification

Power Station

Transmission System

Substations

Switching Stations

Overhead Contact System

Use Made of Existing Structures

BRIDGE WARNINGS

RETURN CIRCUIT

PREVENTION OF INDUCTIVE EFFECTS AND ELECTROLYSIS

TELEPHONE SYSTEM

ELECTRIC LOCOMOTIVES, MULTIPLE-UNIT EQUIPMENT, WORK AND INSPECTION EQUIPMENT

SPARE PARTS

ALTERATIONS TO BRIDGES AND BUILDINGS

CHANGES IN WIRE LINES

CHANGES IN SIGNAL SYSTEMS

REMOVAL AND RE-ESTABLISHMENT OF STEAM LOCOMOTIVE TERMINALS

ROLLING EQUIPMENT TO BE RELEASED

A SUMMARY OF THE PRECEDING SECTIONS RELATING TO INSTALLATION COSTS

THE INDETERMINATE COSTS OF ELECTRIFICATION

THE ESTIMATED COST OF ELECTRIFICATION BY SYSTEMS

A SUMMARY OF COSTS

PART III

A STUDY OF RESULTS WHICH ARE TO BE ANTICIPATED FROM ELECTRIFICATION IN CHICAGO

301. RAILROAD OPERATING EXPENSES AS AFFECTED BY ELECTRIFICATION

CHANGES IN OPERATING EXPENSES ON TRACKAGE WITHIN THE PROPOSED LIMITS OF ELECTRIFICATION

1. MAINTENANCE OF WAY AND STRUCTURES

2. MAINTENANCE OF EQUIPMENT

3. Traffic Expenses

4. Transportation Expenses

5. General Expenses

Summary

OPERATING EXPENSES INCIDENT TO THE PROPOSED NEW TRANSFER STATIONS

EFFECT OF ELECTRIFICATION ON OPERATING EXPENSES RESULTING FROM THE SHORTENING OF STEAM OPERATED DIVISIONS

SUMMARY OF THE EFFECTS OF ELECTRIFICATION UPON OPERATING EXPENSES

302. RESULTS TO BE ANTICIPATED FROM ELECTRIFICATION, THE VALUE OF WHICH IS INDETERMINATE

303. THE EFFECT OF ELECTRIFICATION UPON SAFETY

PART IV

FINANCIAL PRACTICABILITY OF ELECTRIFICATION

401. THE FINANCIAL PRACTICABILITY OF COMPLETE ELECTRIFICATION OF CHICAGO'S RAILROAD TERMINALS

A SUMMARY OF FACTS ESTABLISHED

A

FINANCIAL PRACTICABILITY

PART V

SUMMARY OF CONCLUSIONS WITH REFERENCE TO THE ELECTRIFICATION OF RAILROAD TERMINALS

501. THE NECESSITY, TECHNICAL FEASIBILITY AND FINANCIAL PRACTICABILITY OF ELECTRIFICATION

PART VI

SUMMARY OF CONCLUSIONS WITH REFERENCE TO ATMOSPHERIC POLLUTION

601. RECOMMENDATIONS BASED UPON THE COMMITTEE'S STUDIES

APPENDIX

Territorial Growth of Chicago

Changes in Population of Illinois, of Cook County and of the City of Chicago

ESTIMATES OF FUTURE GROWTH IN POPULATION OF CHICAGO

CHANGES IN POPULATION OF CHICAGO, NEW YORK, BOSTON AND PHILADELPHIA, AND OF THEIR ADJACENT TERRITORY

IMPORTANCE OF CHICAGO AS A RAILROAD CENTER

METEOROLOGICAL CONDITIONS OF CHICAGO

INFLUENCES AFFECTING THE LOCATION OF RAILROAD LINES AND TERMINALS IN CHICAGO

SPREAD OF SOLID MATERIALS IN THE SMOKE OF LOCOMOTIVES

THE PERFORMANCE OF ILLINOIS AND INDIANA COALS WHEN BURNED IN LOCOMOTIVE SERVICE

BIBLIOGRAPHY

ILLUSTRATIONS

SMOKE ABATEMENT

AND

ELECTRIFICATION OF RAILWAY TERMINALS

IN CHICAGO

INTRODUCTION

THE CITY OF CHICAGO

1.01 **Characteristics of a City as Factors in the Definition of its Problems:** The significance of any work in the physical betterment of a city is measured to some extent by the character of that city. The abatement of smoke, the possible elimination of the steam locomotive, the electrification of railroad terminals, are all matters which, in the case of Chicago, present problems co-extensive with the city's activities. No interpretation of them can be satisfactory which fails to take account of these activities.

The investigations, the results of which are presented by this report, concern the city of Chicago. The various studies upon which conclusions are based have touched at many points the municipal, commercial, industrial and domestic life of the city. Facts which are fundamental to a proper interpretation of the conclusions set forth are to be found in the city's history, its rate of growth, its present-day activities and its plans for future development. The purpose of this part of the Committee's report is to present these aspects of the general problem.

1.02 **Early History:** For a century and a half after its discovery by white men the Chicago region was little more than a name vaguely connected with the wilderness. A hundred years ago Chicago itself was still a frontier fort, not ready by two decades for its incorporation as a town. A single generation saw the village of fifteen houses become a city of a hundred thousand inhabitants; the following generation knew it as a great metropolis, the varied interests of which were interwoven with the affairs of continents; the third generation has not yet passed, and Chicago stands as the second city of the United States and the fourth of the world.

In the early history of this region appear the familiar names of the French explorers—Marquette, Joliet and LaSalle. It was LaSalle's Italian lieutenant, Tonty, who, in 1685, erected the fort which was the first building on the site of the present city. The name Chicago, of uncertain Indian origin, became at that time associated with the river, and ultimately with the permanent settlement; but it was more than a century before that settlement was actually begun. In the meantime, the French ceded this region to the English. In 1795 the Pottawatomie Indians made over to the United States a piece of land, six miles square, at the mouth of the Chicago River, "where a fort formerly stood." Here, at the beginning of the nineteenth century, was built another fort named for the Secretary of War who ordered its construction, General Henry Dearborn. And then, in 1804, the first permanent settler, John Kinzie, "the Father of Chicago," arrived and established his fur trade.

The problem of the first generation was twofold; it involved the organization of state and city and the elimination of certain factors unfavorable to growth. Illinois was organized as a territory in 1809 and as a state in 1818. Chicago was incorporated as a town in 1834 and was made a city in 1837. But the advantages of citizenship were limited by the slight degree of protection afforded by the state and city and by the lack of a favorable environment. With the close of the War of 1812 the hostile attitude of the British toward American expansion ceased to be a matter of apprehension, but the Indians were a constant menace. In 1812 they perpetrated the terrible massacre at Fort Dearborn, and for twenty years thereafter fear of the savages held back the tide of immigration. Between 1830 and 1840, however, the Indian tribes were removed, one after another, to the Indian territory; and with the immediate influx of eager colonists, the growth of Chicago was fairly begun.

1.03 Transportation Problems: Although internal conditions were still most primitive, the record of the year 1848 illustrates in a striking manner the city's energy in dealing with the great problem of transportation. Prior thereto, ninety miles of plank road had been built and, as a result of this improvement, 70,000 wagon-loads of produce were, in that year, brought into the town. By the completion of the Illinois and Michigan Canal, connecting the Chicago River with the Illinois River at a point near the head of navigation, a waterway from Lake Michigan to the Mississippi was opened. A National River and Harbor Convention, organized and assembled in Chicago some months earlier, had its influence in a movement which resulted shortly in securing Federal support for these great transportation interests. Finally, toward the close of the year in question, 1848, the first locomotive steamed out of Chicago. In the next decade, 1850–60, rail connections were completely established with the Atlantic Seaboard, with the productive agricultural centers of the Mississippi Valley and with points in Illinois as far south as Cairo. As a result of its improved facilities in transportation the city developed from a retail to a wholesale market, it became a center of distribution between Eastern factories and Northwestern sources of raw products and it established itself as a world city.

1.04 Territorial Growth: Chicago began official life on an area of two and a half square miles. It has extended its boundaries in nearly every decade of its history. The largest single annexation was that of June 29, 1889, in which the added territory included a part of the town of Cicero, the city of Lake View, the towns of Jefferson and Lake and the village of Hyde Park, an area of about 126 square miles, with an estimated population of 210,700. Other annexations included territory varying in extent from small fractions of a square mile to more than eleven square miles. Some of these annexations had no population; three of the largest had populations of from 11,000 to 12,600.

A summary of the city's growth in area, and of its ratio of increase, is set forth by table I.

TABLE I. TERRITORIAL GROWTH OF CHICAGO; AREA AND RATIO OF INCREASE

Year	Area Sq. Miles	Increase in Area Sq. Miles	Ratio of Increase	
			Decade	Total
1835	2.550	......	1.00	1.00
1850	9.760	7.210	3.83	3.83
1860	17.998	15.448	1.84	7.06
1870	35.756	17.758	1.99	14.02
1890	169.836	134.080	4.75	66.60
1910	190.638	20.802	1.12	74.76

1.05 Growth in Population: The basis of the population of Chicago is Anglo-Saxon, Scotch and Teutonic. The early settlers, sturdy, far-seeing and persistent in their struggle with the wilderness, came chiefly from New York and New England. The people, therefore, who created the city belonged to that distinctive racial combination which is recognized as American.

Statistical records of the population of Chicago are available for the period which has elapsed since 1850.[*] For the present purpose it will suffice to show the increase in the city's population since that year and to present an estimate of its future growth. Growth in population is a function of the birth rate, the death rate, migration, immigration and other similar influences. A study based upon all these factors has resulted in the estimates[†] presented in table II.

TABLE II. GROWTH IN POPULATION OF CHICAGO

1850 to 1910		Future Population Estimated 1920 to 1950	
Year	Population	Year	Population
1850	29,375	1920	2,728,434
1860	109,260	1930	3,307,487
1870	298,977	1940	3,927,076
1880	503,185	1950	4,594,418
1890	1,099,850	....	....
1900	1,698,575	....	....
1910	2,185,283	....	....

---

[*] From these records the Committee has compiled an elaborate statement covering fully the various influences which have affected the population, and has set forth a complete analysis of the effect upon population of migration, emigration and immigration. This, with additional facts bearing upon territorial growth, is presented in the Appendix.

[†] For the basis of the estimates see Appendix, section 701.24.

1.06 Chicago as a Manufacturing Center: In the number of its manufacturing establishments, the amount of capital invested in manufacturing and the value of its manufactured output, Chicago, among the cities of the United States, now stands second only to New York. Its advancement as a manufacturing center has been rapid. In 1860 it held seventh place, with but 469 factories against New York's 4,375. By 1910 it had risen to second place, with 9,656 establishments against New York's 25,938.

Statistics dealing with the manufacturing activities of the eight largest cities in the country, for each ten-year period from 1860 to 1910, are shown by tables III to XXIV. These indicate the number of manufacturing establishments, the amount of capital invested and the value of manufactured products. The relative rank of each city in the group is shown, with the rate of its own increase during each decade. In every case the figures presented cover the entire county in which the city is located, thus avoiding the complicating factor of changes which would otherwise arise from decade to decade in the areas compared.

TABLE III. NUMBER OF MANUFACTURING ESTABLISHMENTS
EIGHT LARGEST CITIES OF THE UNITED STATES

City	1860	1870	1880	1890	1900	1910*
New York	4,375	7,624	11,339	25,403	39,776	25,938
Chicago	**469**	**1,440**	**3,519**	**9,977**	**19,203**	**9,656**
Philadelphia	6,298	8,184	8,567	18,166	15,887	8,379
Pittsburgh	1,191	1,844	1,536	2,095	2,831	1,659
St. Louis	1,126	4,579	2,924	6,148	6,732	2,667
Cleveland	387	1,149	1,055	2,307	2,927	2,148
Boston	1,050	2,546	3,665	7,942	7,247	3,155
Baltimore	1,100	2,759	3,683	5,265	6,359	2,502
Group	15,996	30,125	36,288	77,303	100,962	56,104

*The general decrease in the number of establishments for all cities from 1900 to 1910 was caused by the fact that, in 1910, the number of hand industries previously included in manufacturing was not taken into consideration, and the total number of establishments includes factories only.

TABLE 1V. NUMBER OF MANUFACTURING ESTABLISHMENTS
PERCENTAGE OF EACH CITY TO ENTIRE GROUP

City	1860	1870	1880	1890	1900	1910
New York	27.35	25.31	31.24	32.87	39.40	46.24
Chicago	**2.93**	**4.78**	**9.70**	**12.91**	**19.02**	**17.21**
Philadelphia	39.37	27.17	23.61	23.50	15.73	14.93
Pittsburgh	7.45	6.12	4.23	2.71	2.80	2.96
St. Louis	7.04	15.20	8.06	7.95	6.67	4.75
Cleveland	2.42	3.81	2.91	2.98	2.90	3.83
Boston	6.56	8.45	10.10	10.27	7.18	5.62
Baltimore	6.88	9.16	10.15	6.81	6.30	4.46
Group	100.00	100.00	100.00	100.00	100.00	100.00

TABLE V. RATIO OF INCREASE IN THE NUMBER OF MANUFACTURING ESTABLISHMENTS

City	1860	1870	1880	1890	1900	1910
New York	1.00	1.74	2.59	5.81	9.09	5.93
Chicago	**1.00**	**3.07**	**7.50**	**21.27**	**40.94**	**20.59**
Philadelphia	1.00	1.30	1.36	2.88	2.52	1.33
Pittsburgh	1.00	1.55	1.29	1.76	2.38	1.39
St. Louis	1.00	4.07	2.60	5.46	5.98	2.37
Cleveland	1.00	2.97	2.73	5.96	7.56	5.55
Boston	1.00	2.42	3.49	7.56	6.90	3.00
Baltimore	1.00	2.51	3.35	4.79	5.78	2.27
Group	1.00	1.88	2.27	4.83	6.31	3.51

TABLE VI. RATIO OF INCREASE IN THE NUMBER OF MANUFACTURING ESTABLISHMENTS

City	1870	1880	1890	1900	1910
New York	1.00	1.49	3.33	5.22	3.40
Chicago	**1.00**	**2.44**	**6.93**	**13.34**	**6.71**
Philadelphia	1.00	1.05	2.22	1.94	1.02
Pittsburgh	1.00	0.83	1.14	1.54	0.90
St. Louis	1.00	0.64	1.34	1.47	0.58
Cleveland	1.00	0.92	2.01	2.55	1.87
Boston	1.00	1.44	3.12	2.85	1.24
Baltimore	1.00	1.33	1.91	2.30	0.91
Group	1.00	1.20	2.57	3.35	1.86

TABLE VII. RATIO OF INCREASE IN THE NUMBER OF MANUFACTURING ESTABLISHMENTS

City	1880	1890	1900	1910
New York	1.00	2.24	3.51	2.29
Chicago	**1.00**	**2.84**	**5.46†**	**2.74**
Philadelphia	1.00	2.12*	1.85	0.98
Pittsburgh	1.00	1.36	1.84	1.08
St. Louis	1.00	2.10	2.30	0.91
Cleveland	1.00	2.19	2.77	2.04
Boston	1.00	2.17	1.98	0.86
Baltimore	1.00	1.43	1.73	0.68
Group	1.00	2.13	2.78	1.55

*Influenced by Centennial Exposition.
†Influenced by World's Fair.

TABLE VIII. CAPITAL INVESTED IN MANUFACTURES.
RATIO OF CHICAGO TO NEW YORK

1860 Per Cent	1870 Per Cent	1880 Per Cent	1890 Per Cent	1900 Per Cent	1910 Per Cent
9.10	30.30	37.99	84.42	57.93	71.24

TABLE IX. CAPITAL INVESTED IN MANUFACTURES.
PERCENTAGE OF EACH CITY TO ENTIRE GROUP

City	1860	1870	1880	1890	1900	1910
New York	30.67	23.84	27.69	24.86	34.19	32.90
Chicago	**2.79**	**7.23**	**10.52**	**20.98**	**19.80**	**23.43**
Philadelphia	36.74	31.93	28.59	21.89	17.67	16.67
Pittsburgh	10.29	9.96	9.33	7.62	9.02	6.83
St. Louis	6.38	11.08	7.77	8.28	6.01	6.50
Cleveland	1.34	2.50	2.97	4.07	3.65	5.48
Boston	7.28	8.68	7.23	6.89	5.32	4.23
Baltimore	4.51	4.78	5.90	5.41	4.34	3.96
Group	100.00	100.00	100.00	100.00	100.00	100.00

TABLE X. RATIO OF INCREASE IN CAPITAL INVESTED

City	1860	1870	1880	1890	1900	1910
New York	1.00	2.12	2.96	6.96	15.06	22.29
Chicago	**1.00**	**7.07**	**12.36**	**64.57**	**95.85**	**174.45**
Philadelphia	1.00	2.37	2.55	5.12	6.50	9.43
Pittsburgh	1.00	2.64	2.98	6.36	11.85	13.79
St. Louis	1.00	4.74	3.99	11.14	12.74	21.16
Cleveland	1.00	5.10	7.26	26.05	36.72	84.95
Boston	1.00	3.26	3.26	8.14	9.86	12.06
Baltimore	1.00	2.89	4.28	10.29	12.99	18.25
Group	1.00	2.73	3.28	8.59	13.51	20.78

TABLE XI. RATIO OF INCREASE IN CAPITAL INVESTED

City	1870	1880	1890	1900	1910
New York	1.00	1.39	3.28	7.09	10.50
Chicago	**1.00**	**1.75**	**9.14**	**13.56**	**24.68**
Philadelphia	1.00	1.08	2.16	2.74	3.97
Pittsburgh	1.00	1.13	2.41	4.48	5.21
St. Louis	1.00	0.84	2.35	2.69	4.46
Cleveland	1.00	1.42	5.11	7.20	16.67
Boston	1.00	1.00	2.50	3.03	3.70
Baltimore	1.00	1.48	3.56	4.49	6.31
Group	1.00	1.20	3.15	4.95	7.61

TABLE XII. RATIO OF INCREASE IN CAPITAL INVESTED

City	1880	1890	1900	1910
New York	1.00	2.35	5.09	7.53
Chicago	**1.00**	**5.23**	**7.76**	**14.12**
Philadelphia	1.00	2.01	2.55	3.69
Pittsburgh	1.00	2.14	3.98	4.63
St. Louis	1.00	2.79	3.19	5.30
Cleveland	1.00	3.59	5.06	11.70
Boston	1.00	2.50	3.03	3.70
Baltimore	1.00	2.40	3.03	4.26
Group	1.00	2.62	4.12	6.34

TABLE XIII. CAPITAL INVESTED IN MANUFACTURES

City	1860	1870	1880	1890	1900	1910
New York........	$ 61,212,757	$129,952,262	$181,206,356	$ 426,118,272	$ 921,876,081	$1,364,353,000
Chicago..........	**5,571,025**	**39,372,276**	**68,836,885**	**359,739,598**	**534,000,689**	**971,841,000**
Philadelphia......	73,318,885	174,016,674	187,148,857	375,249,715	476,529,407	691,397,000
Pittsburgh........	20,531,440	54,303,474	61,096,069	130,622,081	243,285,403	283,139,000
St. Louis.........	12,733,948	60,357,001	50,832,885	141,872,386	162,179,331	269,392,000
Cleveland........	2,676,963	13,645,018	19,430,989	69,732,761	98,303,682	227,397,000
Boston...........	14,527,880	47,311,906	47,348,384	118,198,539	143,311,376	175,182,000
Baltimore........	9,009,107	26,049,040	38,586,773	92,723,677	117,062,459	164,437,000
Group	$199,582,005	$545,007,651	$654,487,198	$1,714,257,029	$2,696,548,428	$4,147,138,000*

* About 22.5 per cent of the total for the United States.

TABLE XIV. RATIO OF INCREASE IN CAPITAL INVESTED

City	1890	1900	1910
New York..................................	1.00	2.16	3.20
Chicago....................................	**1.00**	**1.48**	**2.70**
Philadelphia..............................	1.00	1.27	1.84
Pittsburgh.................................	1.00	1.86	2.17
St. Louis..................................	1.00	1.14	1.90
Cleveland..................................	1.00	1.41	3.26
Boston.....................................	1.00	1.21	1.48
Baltimore..................................	1.00	1.26	1.77
Group......................................	1.00	1.57	2.42

TABLE XV. THE WESTWARD MOVEMENT OF MANUFACTURING IN THE LAST HALF CENTURY. CAPITAL INVESTED. PROPORTION OF WESTERN CITIES TO GROUP

Item	1860	1910
Total for group......................	$199,582,005	$4,147,138,000
Chicago, St. Louis and Cleveland.......	20,981,936	1,468,630,000
Proportion three cities to group	10.51%	35.41%
Chicago, St. Louis, Cleveland, and Pittsburgh.....................	41,513,376	1,751,769,000
Proportion four cities to group	20.80%	42.24%

TABLE XVI. AVERAGE CAPITAL PER ESTABLISHMENT. EIGHT LARGEST CITIES OF THE UNITED STATES

City	1860	1870	1880	1890	1900	1910‡
New York.........	$13,991	$17,045	$15,981	$16,774	$23,177	$52,600
Chicago...........	**11,879**	**27,342**	**19,561**	**36,057**	**†27,808**	**100,646**
Philadelphia.......	11,642	21,263	21,845	*20,657	29,995	82,515
Pittsburgh.........	17,239	29,449	39,776	62,349	85,936	170,668
St. Louis..........	11,309	13,181	17,385	23,076	24,091	101,009
Cleveland.........	6,917	11,876	18,418	30,227	33,585	105,864
Boston............	13,836	18,583	12,919	14,883	19,775	55,525
Baltimore.........	8,190	9,441	10,477	17,611	18,409	65,722
Group..........	$12,477	$18,092	$18,036	$22,176	$26,709	$73,919

* Affected by influx of industries following the Centennial Exposition.

† Affected by influx of industries following the Columbian Exposition.

‡ The apparently large increase here indicated arises from the method of enumeration, the number of hand industries being eliminated from the count as explained under table III.

TABLE XIX. RATIO OF INCREASE IN VALUE OF MANUFACTURED PRODUCTS

City	1860	1870	1880	1890	1900	1910
New York..........	1.00	2.09	2.97	4.88	8.62	12.76
Chicago............	**1.00**	**6.83**	**18.37**	**49.03**	**65.58**	**94.51**
Philadelphia........	1.00	2.37	2.39	4.25	4.44	5.49
St. Louis...........	1.00	5.75	4.14	8.30	8.46	11.90
Cleveland..........	1.00	3.88	6.97	16.24	20.05	39.00
Pittsburgh.........	1.00	3.34	3.37	5.79	9.69	9.17
Boston.............	1.00	2.96	3.46	5.60	5.47	6.30
Baltimore..........	1.00	2.81	3.72	6.72	7.65	8.87
Group...........	1.00	2.78	3.52	6.69	9.01	12.43

TABLE XX. RATIO OF INCREASE IN VALUE OF MANUFACTURED PRODUCTS

City	1870	1880	1890	1900	1910
New York....................	1.00	1.42	2.33	4.12	6.10
Chicago......................	**1.00**	**2.69**	**7.18**	**9.61**	**13.85**
Philadelphia................	1.00	1.01	1.79	1.87	2.32
St. Louis....................	1.00	0.72	1.44	1.47	2.07
Cleveland....................	1.00	1.80	4.19	5.17	10.05
Pittsburgh...................	1.00	1.01	1.73	2.90	2.74
Boston..	1.00	1.17	1.89	1.85	2.13
Baltimore....................	1.00	1.32	2.39	2.72	3.16
Group.....................	1.00	1.26	2.40	3.24	4.46

TABLE XXI. RATIO OF INCREASE IN VALUE OF MANUFACTURED PRODUCTS

City	1880	1890	1900	1910
New York..............................	1.00	1.64	2.90	4.29
Chicago................................	**1.00**	**2.67**	**3.57**	**5.14**
Philadelphia..........................	1.00	1.78	1.86	2.30
St. Louis..............................	1.00	2.00	2.04	2.87
Cleveland..............................	1.00	2.33	2.88	5.60
Pittsburgh.............................	1.00	1.71	2.87	2.72
Boston.................................	1.00	1.62	1.58	1.82
Baltimore..............................	1.00	1.81	2.06	2.38
Group................................	1.00	1.90	2.56	3.53

TABLE XVII. VALUE OF MANUFACTURED PRODUCTS. EIGHT LARGEST CITIES OF THE UNITED STATES

City	1860	1870	1880	1890	1900	1910
1	2	3	4	5	6	7
New York........	$159,107,369	$332,951,520	$472,926,437	$777,222,721	$1,371,358,468	$2,029,693,000
Chicago..........	**13,555,671**	**92,518,742**	**249,022,948**	**664,567,923**	**888,945,311**	**1,281,171,000**
Philadelphia......	135,979,777	322,004,517	324,342,935	577,234,446	603,466,526	746,046,000
Pittsburgh	26,563,379	88,789,414	89,646,825	153,738,636	257,398,218	243,454,000
St. Louis.........	27,610,070	158,761,013	114,333,375	229,157,343	233,629,733	328,495,000
Cleveland........	6,973,737	27,049,012	48,604,050	113,240,115	139,849,806	271,961,000
Boston...........	37,681,808	111,380,840	130,531,993	210,936,616	206,081,767	237,457,000
Baltimore........	21,083,517	59,219,933	78,417,304	141,723,599	161,249,240	186,978,000
Group	$428,555,328	$1,192,674,991	$1,507,825,867	$2,867,821,399	$3,861,979,069	$5,325,255,000

TABLE XVIII. VALUE OF MANUFACTURED PRODUCTS. PERCENTAGE OF EACH CITY TO ENTIRE GROUP

City	1860	1870	1880	1890	1900	1910
New York.........	37.13	27.92	31.36	27.10	35.51	38.11
Chicago...........	**3.16**	**7.76**	**16.52**	**23.17**	**23.02**	**24.06**
Philadelphia.......	31.73	27.00	21.51	20.13	15.63	14.01
Pittsburgh.........	6.20	7.44	5.95	5.36	6.66	4.57
St. Louis..........	6.44	13.31	7.58	7.99	6.05	6.17
Cleveland.........	1.63	2.27	3.22	3.95	3.62	5.11
Boston............	8.79	9.34	8.66	7.36	5.34	4.46
Baltimore.........	4.92	4.96	5.20	4.94	4.17	3.51
Group...........	100.00	100 00	100.00	100.00	100 00	100.00

TABLE XXII. RATIO OF INCREASE IN VALUE OF MANUFACTURED PRODUCTS

City	1890	1900	1910
New York	1.00	1.76	2.61
Chicago	**1.00**	**1.34**	**1.93**
Philadelphia	1.00	1.05	1.29
St. Louis	1.00	1.02	1.43
Cleveland	1.00	1.23	2.40
Pittsburgh	1.00	1.67	1.58
Boston	1.00	0.98	1.13
Baltimore	1.00	1.14	1.32
Group	1.00	1.35	1.86

TABLE XXIII. PERCENTAGE OF GAIN IN VALUE OF MANUFACTURED PRODUCTS

1900–1910

City	Per Cent
New York	48
Chicago	**44**
Philadelphia	24
St. Louis	41
Cleveland	94
Pittsburgh	5*
Boston	15
Baltimore	16

* Loss.

TABLE XXIV. MANUFACTURES. RANK OF CHICAGO IN THE GROUP

Items	1860	1870	1880	1890	1900	1910
In number of manufacturing establishments	7th	7th	5th	3d	2d	2d
In capital invested	7th	6th	3d	3d	2d	2d
In value of products	7th	5th	3d	2d	2d	2d

Figs. 1, 2 and 3 present statistics of manufactures in the eight largest cities of the United States, for the period from 1860 to 1910, arranged in diagrammatic form. The exhibit includes the number of manufacturing establishments, amount of capital invested, number of wage earners (men, women and children), amount received by wage earners, cost of materials used, and value of products.

The value of the manufactured products of Chicago for 1910, in terms of the amounts represented by each industry, is shown by table XXV. It will be seen that one-fourth of the total value of the city's manufactured products is represented by the slaughtering and meat-packing industries. The value of Chicago's output in this one industry represents nearly one-quarter of the total for the United States. The total value of the city's manufactured products constitutes two-thirds of the value of the manufactured products of the entire state of Illinois, itself the most important manufacturing state west of the Alleghany Mountains.

TABLE XXV. VALUE OF THE MANUFACTURED PRODUCTS OF CHICAGO'S PRINCIPAL INDUSTRIES, 1910

Industry	Amount
Slaughtering and meat-packing	$325,062,000
Foundry and machine-shop products	89,669,000
Clothing, men's, including shirts	85,296,000
Printing and publishing	74,211,000
Iron and steel, steel works and rolling mills	45,984,000
Lumber and timber products	32,709,000
Bread and other bakery products	26,908,000
Cars, steam-railroad, not incl. operations of companies	20,892,000
Electrical machinery, apparatus and supplies	20,669,000
Furniture and refrigerators	20,512,000
Soap	19,939,000
Coffee and spice, roasting and grinding	19,593,000
Liquors, malt	19,512,000
Paint and varnish	18,942,000
Tobacco manufactures	16,633,000
Clothing, women's	15,677,000
Cars, repairs by companies	15,359,000
Leather, tanned, curried and finished	13,244,000
Copper, tin and sheet-iron products	12,242,000
Musical instruments, pianos, organs and materials	11,487,000
Confectionery	11,222,000
Patent medicines and drugs	10,360,000
All other industries not enumerated	355,049,000
All industries	$1,281,171,000

It is of interest to note the extent of Chicago's wholesale trade in connection with that of its manufacturing industries. This trade in 1912 amounted to about $2,000,000,000. The figures for the period from 1902 to 1911, inclusive, are set forth in table XXVI.

TABLE XXVI. WHOLESALE TRADE AND MANUFACTURED PRODUCTS OF CHICAGO, 1902–1911*

Year	Wholesale Trade	Manufactured Products	Total
1902	$1,298,200,000	$1,195,460,000	$2,493,660,000
1903	1,442,437,000	1,226,901,000	2,669,338,000
1904	1,550,270,000	1,280,000,000	2,830,270,000
1905	1,767,304,000	1,420,800,000	3,188,104,000
1906	1,855,600,000	1,491,840,000	3,347,440,000
1907	1,911,268,000	1,525,000,000	3,436,268,000
1908	1,825,263,000	1,410,625,000	3,285,888,000
1909	1,916,526,150	1,495,262,500	3,411,788,650
1910	1,954,860,000	1,549,091,000	3,503,951,000
1911	1,905,989,000	1,487,128,325	3,393,117,325

* Dun's Review.

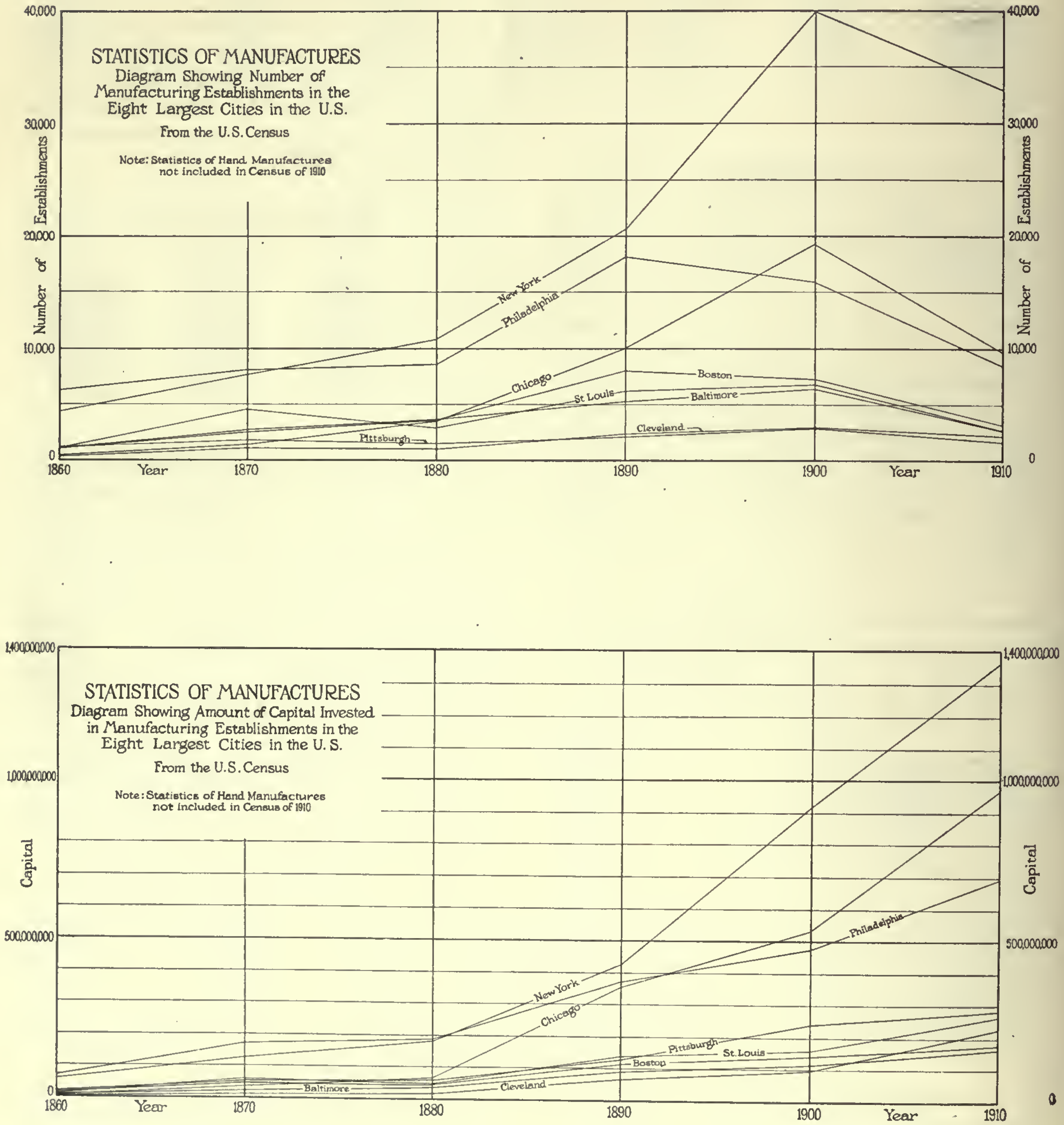
1.07 Chicago as a Mercantile Center: Chicago's location in the midst of an abundant supply of raw materials—the coal of Illinois and Indiana, the iron and copper of Minnesota and northern Michigan, and in earlier years the timber of Michigan and Wisconsin—has determined its character as a manufacturing city. Its position as the gateway to an unrivaled area of fertile and rapidly developing agricultural territory early made it a center of interchange for the products of the soil and the output of factories. The proximity of extensive food supplies and fuels, its favorable climate, the character of its population, the possession of transportation facilities which have the advantages of a strategic location, and its financial resources, are some of the factors which have influenced the development of its mercantile interests. No large city of the United States is situated as near to the center of population and of area as is Chicago.

Chicago's receipts of live stock at the Union Stock Yards for 1911 with a statement of the value of such stock are shown by table XXVII.

TABLE XXVII. RECEIPTS OF LIVE STOCK IN CHICAGO, 1911*

Item	Number	Valuation
Cattle	2,931,831	$180,206,174
Calves	521,512	5,788,785
Hogs	7,103,360	110,037,446
Sheep	5,736,244	24,634,185
Horses	104,545	18,818,100
Totals	16,397,492	$339,484,690

* Publication of the Civic-Industrial Committee of the Chicago Association of Commerce, by George E. Plumbe, 1911.


STATISTICS OF MANUFACTURES
Diagram Showing Number of Manufacturing Establishments in the Eight Largest Cities in the U.S.
From the U.S. Census
Note: Statistics of Hand Manufactures not included in Census of 1910

STATISTICS OF MANUFACTURES
Diagram Showing Amount of Capital Invested in Manufacturing Establishments in the Eight Largest Cities in the U.S.
From the U.S. Census
Note: Statistics of Hand Manufactures not included in Census of 1910

FIG. 1. STATISTICS OF MANUFACTURES

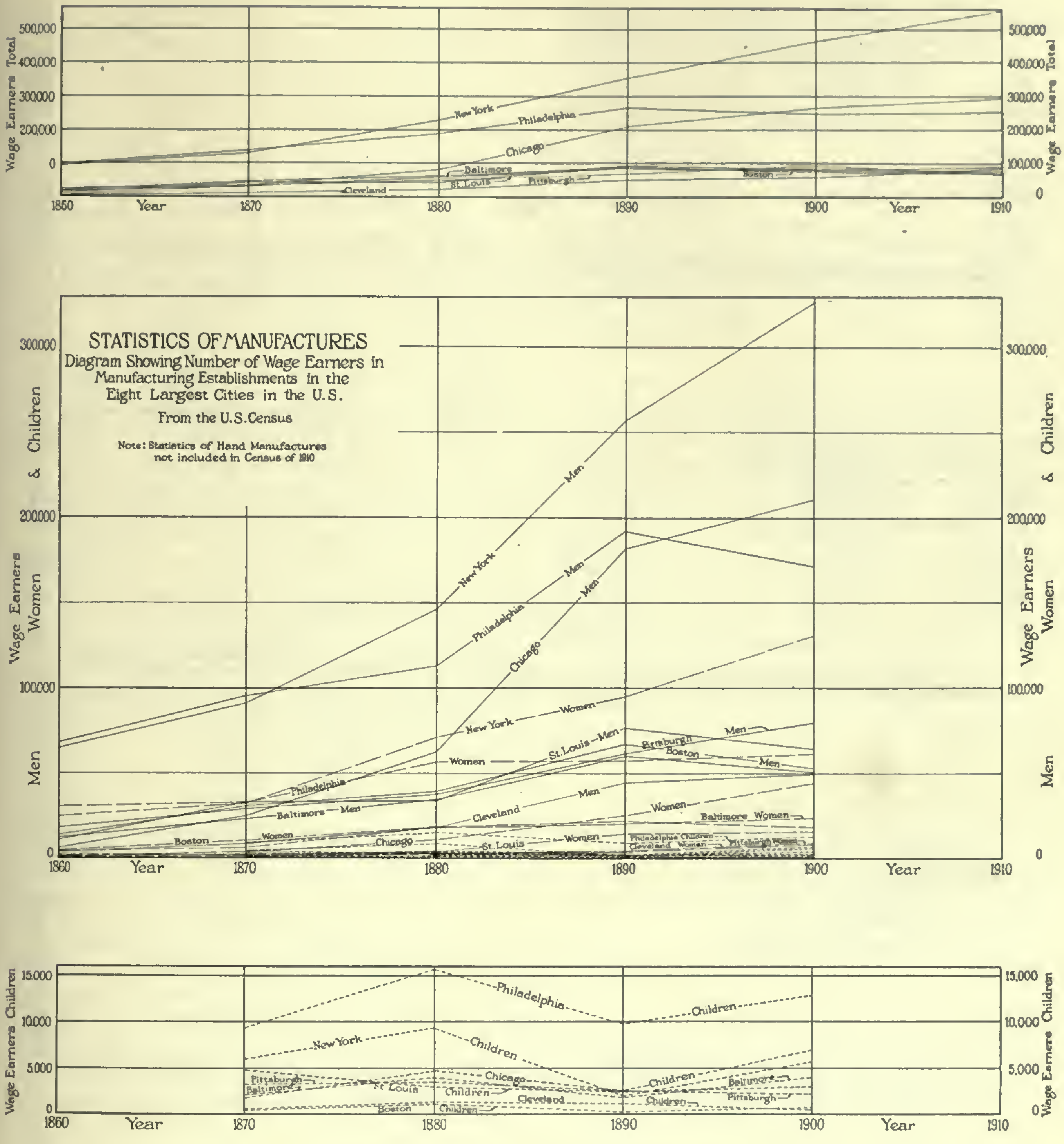
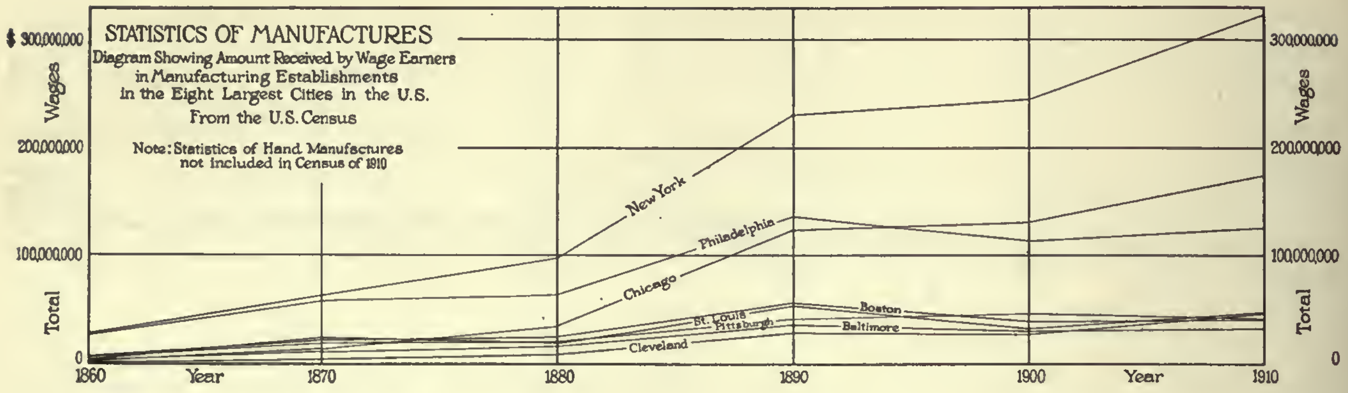
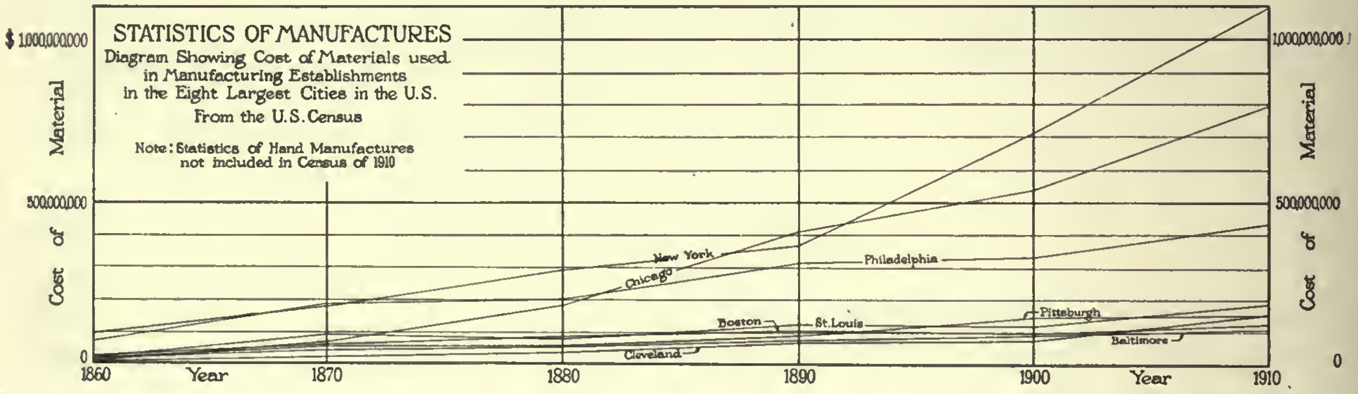


FIG. 2. STATISTICS OF MANUFACTURES





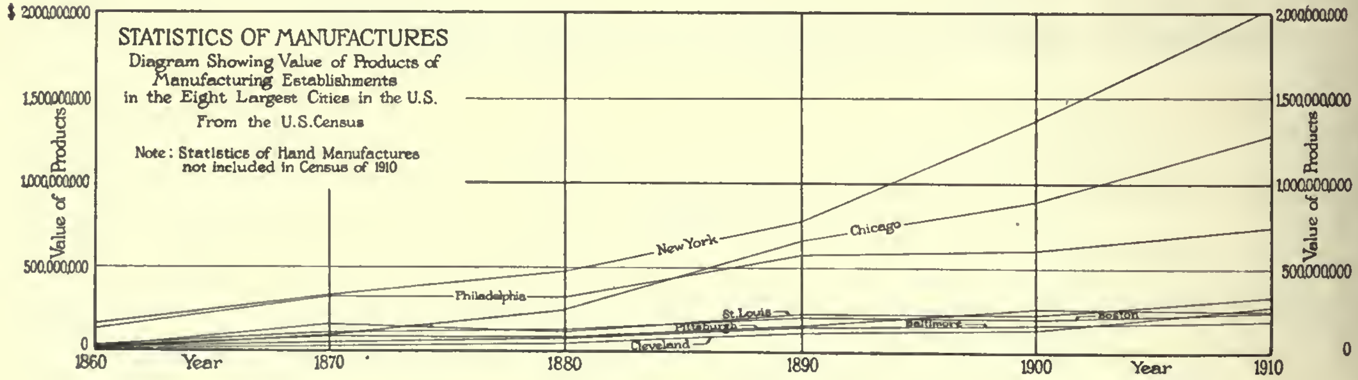


FIG. 3. STATISTICS OF MANUFACTURES

The grain trade began to center in Chicago as soon as the Illinois and Michigan Canal, the Galena & Chicago Union Railroad and lake freight traffic enabled successful competition with other lake ports. With the growth in volume of trade, the necessity for storage at the close of lake navigation developed the city's grain elevator business on a very large scale. At the present time Chicago handles more grain than any other city in the world. Its grain receipts and shipments since 1869 are indicated by table XXVIII.

TABLE XXVIII. GROWTH AND EXTENT OF CHICAGO'S GRAIN TRADE

Year	Total Grain Receipts, Bushels	Total Grain Shipments, Bushels	Flour Manufactured in Chicago, Barrels
1869	37,235,027	31,108,759	232,000
1870	60,432,574	54,745,903	443,967
1880	165,855,370	154,377,115	196,041
1890	219,052,518	204,674,918	430,609
1900	349,637,295	265,552,246	1,274,776
1910	294,858,724	214,601,080	1,090,000
1912	322,008,041	244,423,142	1,108,000
1913	382,270,000	272,843,000	....

Chicago's receipts and shipments of principal commodities in 1911 and 1912 are shown by table XXIX.

TABLE XXIX. CHICAGO'S RECEIPTS AND SHIPMENTS OF PRINCIPAL COMMODITIES

Commodity	Receipts		Shipments	
	1911	1912	1911	1912
Pork, bbl	9,050	9,737	105,913	138,752
Other meats, lb.	228,741,800	153,990,300	550,849,300	566,627,100
Lard, lb	42,171,300	61,228,100	302,699,100	252,176,100
Butter, lb	334,932,400	287,798,800	285,685,400	271,109,500
Wool, lb	71,810,800	55,778,600	139,688,600	98,691,600
Hides, lb	166,130,800	149,058,500	194,764,900	162,800,300
Flaxseed, bu	959,500	2,298,500	165,600	409,100
Other seeds, lb	37,644,100	44,120,000	36,964,200	59,513,500
Salt, bbl	1,659,799	2,008,694	523,653	671,830
Lumber, ft	2,134,567,000	2,693,305,000	803,923,000	1,002,373,000
Eggs, cases	4,707,325	....	3,145,678	....
Flour, bbl	5,859,396	7,070,898	5,781,092	6,268,876
Wheat, bu	37,118,100	35,914,000	23,339,500	35,726,100
Corn, bu	108,550,500	112,690,000	87,930,600	73,739,100
Oats, bu	94,099,800	118,491,300	77,428,500	102,077,000

Trade involves financial activities. Much of the money, credit and exchange necessary in moving the crops not only of the United States, but of Canada, centers in Chicago. Table XXX shows some of the more significant financial transactions of 1912 and 1913.

In bank clearings Chicago leads all other cities of the United States except New York. Its relation to that city, and to each of the other cities of the United States having a population of 300,000 or more, is shown for the years 1910 and 1911 by table XXXI. Chicago's bank clearings for the years 1912 and 1913 are presented in table XXX.

TABLE XXX. EXTENT OF CERTAIN OF CHICAGO'S FINANCIAL AND TRADE ACTIVITIES

Item	1912	1913
Bank clearings	$15,380,795,541	$15,904,950,974
Board of Trade clearings	70,338,000	70,000,000
Bank deposits at end of year	975,000,000	1,001,000,000
Sub-treasury receipts	800,600,000	805,000,000
Value of live stock received	378,450,000	409,163,674
Real estate transfers, number	42,425	54,092
Real estate considerations	171,325,389	135,669,729
Value of building permits	88,043,000	88,920,800
Value of imported merchandise	30,278,600	33,284,656
Customs receipts	10,676,601	11,112,587
Bonds sold, Stock-Exchange	13,757,000	9,315,000
Fire insurance losses	6,400,000	6,000,000
Grain receipts in bushels	287,438,000	332,527,000
Grain shipments in bushels	216,213,000	245,940,000
Flour receipts, barrels	7,070,898	10,051,000
Flour shipments, barrels	6,268,876	6,050,000
Grain lake shipments, bushels	47,608,600	54,292,249
Grain cars inspected	185,589	207,045
Lake commerce, tonnage	17,065,541	17,999,264
Lumber receipts, feet	2,693,305,000	2,800,276,000
Lumber shipments, feet	1,002,373,000	941,821,000
Receipts of live stock, head	16,487,233	16,452,807
Shares sold, Stock-Exchange	1,174,931	990,402
Building permits issued	11,212	10,867

TABLE XXXI. COMPARATIVE STATEMENT OF BANK CLEARINGS

City	1910	1911
New York	$97,274,500,093	$92,372,812,735
Chicago	**13,939,689,984**	**13,925,709,802**
Philadelphia	7,689,664,084	7,691,842,937
St. Louis	3,727,949,379	3,859,681,136
Boston	8,299,320,162	8,339,718,582
Baltimore	1,626,676,299	1,767,682,328
Pittsburgh	2,587,325,785	2,520,285,913
Cleveland	1,000,857,953	1,012,557,805
Buffalo	502,826,696	516,876,771
San Francisco	2,323,772,876	2,427,075,543
Detroit	924,835,008	968,647,059
Cincinnati	1,251,797,050	1,277,555,300
Milwaukee	658,002,572	696,732,779
New Orleans	978,491,235	1,013,907,623
Washington	365,656,582	369,167,396

The record of money orders handled by the postoffice may be accepted as an indication of business activity. In respect to these, Chicago and New York far outrank other cities of the United States. A comparative record of the postal money order transactions of Chicago and New York is shown by table XXXII.

TABLE XXXII. POSTAL MONEY ORDER BUSINESS OF NEW YORK AND CHICAGO IN 1911

City	Total Receipts	Domestic Money Orders	
		Issued	Paid
New York	$24,190,109.65	$14,339,500.72	$59,675,454.06
Chicago	**20,317,374.57**	**11,933,117.09**	**96,505,881.72**

The receipts of the Chicago postoffice for 1912 amounted to $21,625,146; domestic money orders paid, $100,322,444; certificates of deposit issued, $115,335,823; total of transactions, $249,979,693.

Chicago's importance as a lake port is shown by the extent of its arrivals and clearances. In 1911 the arrivals by lake amounted to 7,935,969 tons and in 1912 to 8,471,023 tons; the clearances amounted in 1911 to 8,021,036 tons and in 1912 to 8,594,518 tons.

Some of the principal shipments by lake in 1911 and 1912 are shown by tables XXXIII and XXXIV.*

TABLE XXXIII. SHIPMENTS FROM CHICAGO BY LAKE

Commodity	1911	1912
Flour, barrels	2,837,725	2,762,291
Wheat, bushels	14,598,973	17,523,384
Corn, bushels	47,964,537	24,599,769
Oats, bushels	10,759,852	5,345,172
Wool and hair, sacks	10,845	4,522
Iron, manufactured, tons	60,015	146,135
Oil, barrels	643,179	899,038
Mdse. unclassified, tons	461,845	442,222

TABLE XXXIV. RECEIPTS AT CHICAGO BY LAKE

Commodity	1911	1912
Coal, hard, tons	969,231	881,380
Coal, soft, tons	560,093	831,579
Salt, tons	209,134	166,696
Iron ore, tons	4,086,276*	5,558,000†
Iron, manufactured, tons	64,660	47,097
Cement, tons	4,586	6,449
Lumber, feet	280,159,000	284,596,000
Shingles, (M)	4,816	1,660
Lath, (M)	6,375	11,967
Posts, pieces	168,264	63,340
Railroad ties	726,050	320,315
Telegraph poles	2,145	....
Wood, cords	2,525	2,970
Copper, tons	9,754	1,245
Sugar, tons	81,828	88,874
Green fruits, tons	66,480	48,717
Wheat, bushels	641,883	3,660,712
Barley, bushels	58,000	11,116
Corn, bushels	30,000	13,941
Mdse. unclassified, tons	781,206	....

* Exclusive of 1,305,387 tons received at Gary, Ind.

† Exclusive of 2,073,219 tons received at Gary, Ind., and 387,914 tons received at Indiana Harbor, Ind.

The extent of Chicago's rail freight tonnage may be judged from the number of freight cars arriving at and departing from the city in a given year. Table XXXV shows the number of cars handled by 21 railroads in 1912 (section 203.10, tables CCXVIII to CCXXIII, inclusive). The number of cars received or the number of cars delivered annually is approximately three times the whole number of freight cars owned by all the railroads of the country, and the total movement is equivalent to three trips each year into and out of Chicago for every freight car in the country.

TABLE XXXV. CHICAGO'S RAIL FREIGHT TRAFFIC

Item	Number Cars 1912	Percentage Increase 1903–1912
Received	7,373,603	58.9
Forwarded	7,453,136	59.6
Totals	14,826,739	59.2
Less-than-carload freight received, tons		3,207,126
Less-than-carload freight forwarded, tons		5,342,504

Twenty-five hundred package cars (cars carrying less-than-carload lots and going through to destination without breaking seal) leave Chicago daily for 32,000 destinations which are reached without transfer, or with but one transfer and that near the point of destination. The accompanying map, fig. 4, suggests the extent of this service. The reduction in size of the map has made it necessary to omit all except the more important points in the territory near Chicago.

1.08 The Population of Chicago and of its Industrial Zone: In its study of statistics relating to population the Committee has sought to compare the growth of Chicago's population with that of the population of three other large centers of industry. For this purpose it has considered the population of each city and also of an outlying area including the counties within a radius of 50 miles. This area including the city in each case is to be regarded as the industrial zone of the city in question. In the case of Chicago the industrial zone includes the counties of Cook, Dupage, Grundy, Kane, Kankakee, Kendall, Lake, McHenry and Will in Illinois, and those of Lake, Laporte and Porter in Indiana. For the purposes of this study the area as defined for Chicago has been divided into three zones, as follows: Zone A includes the area within the city limits of Chicago; Zone B includes an outlying area between the city limits and the line which marks the limits of the Committee's Area of Investigation (section 103.04); and Zone C includes that portion of the industrial zone, as defined above, which lies outside of Zones A and B. Table XXXVI shows the areas of the three zones and the density of population.

The population and density of the four largest industrial zones in the United States, those of New York, Philadelphia, Boston and Chicago, are set forth in table XXXVII.

During the interval covered by the last two decades, 1890 to 1910, the combined population of the industrial zones of these four cities increased 68.04 per cent, or from 10,630,579 in 1890 to 17,863,603 in 1910, while the population of Chicago's industrial zone increased 91.31 per cent, or from 1,530,135 to 2,927,357.

The increases in the population of the similar industrial zones of which New York, Boston and Philadelphia respectively are the centers, were 85.20 per cent for New York, 51.20 per cent for Boston and 41.51 per cent for Philadelphia.

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*Chicago Daily News Almanac, 1913.

The city of Chicago alone furnishes a much larger proportion of the total population of its zone than do any of the three other cities, the ratio for Chicago being 71.88 per cent in 1890, 75.39 per cent in 1900 and 74.65 per cent in 1910.

TABLE XXXVI. COMPARATIVE POPULATION (1910), AREA AND DENSITY OF ZONES A, B AND C, CHICAGO

Zone	Population					Area (Square Miles)			Population per Square Mile		
		Urban		Rural							
	Total.	Total	Per Cent of Total Population	Total	Per Cent of Total Population	Total	Incorporated	Unincorporated	Total	Urban	Rural
1	2	3	4	5	6	7	8	9	10	11	12
A	2,185,283	2,185,283	100.0	......	....	190.6	190.6	......	11,465.3	11,465.3	....
B	194,869	185,517	95.2	9,352	4.8	237.0	114.6	122.4	822.2	1,618.8	76.4
C	547,205	338,830	61.9	208,375	38.1	6,253.4	285.2	5,968.2	87.5	1,188.0	34.9
Grand totals	2,927,357	2,709,630	92.6	217,727	7.4	6,681.0	590.4	6,090.6	438.2	4,589.5	35.7

TABLE XXXVII. COMPARATIVE POPULATION AND DENSITY OF THE FOUR LARGEST INDUSTRIAL ZONES IN THE UNITED STATES

Year	New York Zone		Philadelphia Zone		Boston Zone		Chicago Zone	
	Population		Population		Population		Population	
	Total	Per Square Mile	Total	Per Square Mile	Total	Per Square Mile	Total	Per Square Mile
1	2	3	4	5	6	7	8	9
1860	1,990,477	260.4	1,523,174	142.4	1,283,386	174.8	340,626	51.0
1870	2,554,155	334.1	1,778,638	166.3	1,523,667	207.5	598,563	89.6
1880	3,223,064	421.6	2,126,323	198.8	1,885,164	256.7	889,415	133.1
1890	4,184,216	547.4	2,540,024	237.4	2,376,204	323.6	1,530,135	229.0
1900	5,624,443	735.8	3,006,434	281.0	2,981,076	405.9	2,252,960	337.2
1910	7,748,963	1013.7	3,594,476	336.0	3,592,807	489.2	2,927,357	438.2

1.09 Chicago as a Center of Transportation Activity: Geographical conditions make the site of Chicago a natural rendezvous. Paths of easy travel, defined by the configuration of the land and water areas of a continent, approach from many directions. As the chief port of an inland ocean, Chicago is to be compared with a coast city. The lakes make possible a direct shipping trade with eight states; they give access to the St. Lawrence River and thence to the Atlantic Ocean; while to the southward are the possible water routes connecting Chicago with the Mississippi River and the Gulf of Mexico.

The topography of the country makes Chicago the logical point of juncture between the East and the Northwest. The early French explorers who dreamed of founding an empire centering in the Mississippi Valley, were quick to see the advantages of a port at the head of "the Lake of the Illinois." Joliet pointed out to the Canadian authorities how easy it would be to go from Lake Erie to the Mississippi "in boats by a very good navigation," by cutting a channel through half a league of prairie between "the Lake of the Illinois and the St. Louis River." The natural lines of communication by land between East and West also were early indicated by the movements of the pioneers. Whether they came from New England or from the Middle States or even from the Southern States, the easiest pathways to the great West ran through Chicago.

These are some of the primary factors which have influenced the growth of the transportation activities of Chicago. Efforts were made in the earlier years to improve the natural facilities for transportation, and in 1837 the state of Illinois made provision for the betterment of navigation on the Wabash, Illinois, Rock, Kaskaskia and Little Wabash rivers. In that year the state authorized the construction of railroads from Vincennes to St. Louis; from Cairo to the northern terminus of the proposed Illinois and Michigan Canal and thence to Galena; from Alton to Mount Carmel and from Alton to Shawneetown; from Quincy to Springfield and thence to the Indiana State Line; and of various other roads, totaling in all 1,341 miles. At this time the money in the state treasury was not sufficient for the construction of these railroads, the estimates requiring $10,000,000 more than the amount on hand. Bonds were therefore sold and scrip was issued to contractors on account of the proposed improvements. A short line extending from Springfield to Meredosia was completed and operated at a loss; some work was done on other lines but the scheme finally collapsed, leaving the state wiser and poorer as a result of its experiment.

FIG. 4. RANGE OF DISTRIBUTION OF L. C. L. FREIGHT FROM CHICAGO BY PACKAGE CAR SYSTEM

Numerals Indicate Number of Days Between Shipment and Arrival

(Courtesy of "Chicago Commerce.")

Chicago's first railroad was opened to traffic in 1848 with an equipment of one locomotive and six freight cars. This was the Galena & Chicago Union Railroad, which had received its charter on January 16, 1836. Galena was then one of the leading villages to the west of Chicago. The survey of the route was begun thirteen months after the granting of the charter but was stopped in June, 1837, when prosecution of the enterprise ceased for a time. Work was resumed in December, 1846, and in 1848 rails were laid to the Chicago River.

In 1850 Illinois possessed 111 of the 9,200 miles of railroad in the United States.

The future of Chicago as a railroad center was assured within the twelve years from 1848 to 1860. During this period ten of the present trunk lines commenced operation, with Chicago as the objective point. Seven of these lines were from the west and had their origin at different points in the Mississippi Valley, while the other three were from the east.

In 1860 there were eleven trunk lines running into Chicago, the aggregate mileage of which was more than 4,700 miles and the earnings of which were in excess of $13,000,000 annually. In 1869 the trunk lines numbered twelve, with an aggregate of more than 7,000 miles of line, and total earnings amounting to about $50,000,000 annually.

The three decades from 1860 to 1890 may be characterized as the real period of growth of Chicago's transportation activities. Of the 39 roads at present operating in the Chicago terminals and included in the scope of the Committee's investigation, 19 have been of special significance in the establishment of transportation connection between Chicago and other sections of the country, in distinction from those which perform more limited or purely local service. The beginnings of these roads are summarized in the following paragraphs.

The Atchison, Topeka & Santa Fe Railway Company received its charter in the name of the Atchison & Topeka Railroad Company, February 15, 1859. The line between Kansas City and Chicago was opened in May, 1888.

The Baltimore & Ohio Railroad Company was chartered in Maryland on February 28, 1827, and secured an entrance into Chicago in November, 1874, over the lines of the Illinois Central Railroad Company, with which company a contract was also made for the use of station grounds.

The Chicago & Alton Railroad Company was a development of the Alton & Sangamon Railroad Company, which was chartered by special act of the legislature, February 27, 1847. The railroad obtained entrance into Chicago through lease of the Joliet & Chicago Railroad, which was opened July 4, 1856.

The Chicago & Eastern Illinois Railroad Company was first organized and constructed as the Chicago, Danville & Vincennes Railroad Company. It was chartered February 16, 1865, and the main line from Chicago to Terre Haute was placed in operation under its control in the fall of 1872.

The Chicago & Erie Railroad Company forms its western extension through the line originally organized as the Chicago & Atlantic Railroad Company, between Hammond, Ind., and Marion, Ohio, a distance of 249 miles. Entrance to Chicago was obtained over the tracks of the Chicago & Western Indiana Railroad Company and through traffic was opened June 17, 1883.

The Chicago & North Western Railway Company, as it exists today, is a consolidation of 45 separate railroads, the first of which in the order of time was the Galena & Chicago Union Railroad already mentioned. This road was completed to Chicago in 1848.

The Chicago, Burlington & Quincy Railroad Company, like most of the great trunk lines entering Chicago, had a comparatively small beginning. It was incorporated originally as the Aurora Branch Railroad Company, February 12, 1849. Entrance to Chicago was secured in June, 1864, over the tracks of the Galena & Chicago Union Railroad from a junction 30 miles west of Chicago.

The Chicago, Indianapolis & Louisville Railway Company was organized July 8, 1847, under the name of the Louisville, New Albany & Chicago Railroad Company. The incorporation took place under a law of the state of Indiana authorizing companies to complete any of the unfinished works of the state. The company started operation into Chicago under the name of the Chicago & Indianapolis Air Line Railway Company in 1880.

The Chicago, Milwaukee & St. Paul Railway Company had its starting point at Milwaukee and its nucleus was the Milwaukee & Mississippi Company, organized in 1849. Ground was broken in 1856 and trains began running to Prairie Du Chien in April, 1857. In 1866 this railroad was absorbed by the Milwaukee & St. Paul Railway Company, which extended its line to Chicago in 1873.

The Chicago, Rock Island & Pacific Railway Company was the outgrowth of a plan, first suggested in 1828, to build a line from Chicago towards the Pacific Coast. A charter was issued to the Rock Island & LaSalle Railroad Company February 27, 1847. On February 7, 1851, the name was changed to the present title and the line between Chicago and Joliet was opened for service October 18, 1852.

The Grand Trunk Western Railway, like many of the others, is the result of a number of consolidations which were finally consummated in 1880 in connection with the Chicago & Grand Trunk Railroad. The line between Chicago and Valparaiso was opened for traffic on February 1, 1880.

The Illinois Central Railroad Company was chartered on February 10, 1851. The road from Chicago to Kensington (then known as Calumet) was completed for connection with the Michigan Central Railroad and opened for traffic May 24, 1852. In July, 1852, the Chicago division from Chicago to Urbana, Ill., was opened for traffic and the road was completed to Cairo, Ill., September 27, 1857.

The Lake Shore & Michigan Southern Railway Company was formed by the consolidation of a number of small lines between the years 1867 and 1869, the present name of the corporation being first used in the latter year. Entrance to Chicago was obtained in 1853 by the Michigan Southern & Northern Indiana Railroad, which was one of the small lines from which the Lake Shore & Michigan Southern Railway was formed.

The Michigan Central Railroad Company succeeded to the franchise of the Detroit & St. Joseph Railroad Company, incorporated in 1831. In 1839, when this line was being extended between Ann Arbor and Jackson, Mich., it was stated that "the rails were not all of iron; when these were not obtainable oak was substituted." The extension to Kensington was placed in operation in May, 1852.

The Minneapolis, St. Paul & Sault Ste. Marie Railway Company is successor to the Wisconsin Central Railroad Company, organized June 17, 1887, under the general laws of Wisconsin, and incorporated for the purpose of acquiring possession and control of a number of different railroads. Among the railroads acquired was the Chicago, Wisconsin & Minnesota Railroad Company, which had opened a line between Chicago and Schleisingerville, Wis., in July, 1886.

The New York, Chicago & St. Louis Railroad Company was incorporated under the General Railroad Act of Illinois, March 23, 1881, and had for its object the construction and operation of a line running from Buffalo to Chicago. On September 1, 1882, operation into Chicago was inaugurated.

The Pennsylvania Company was chartered by the legislature of Pennsylvania in 1890, to acquire all the varied interests of the lines west of Pittsburgh. Of the many lines managed by this company, the Pittsburgh, Fort Wayne & Chicago Railway and the Pittsburgh, Cincinnati, Chicago & St. Louis Railway find a terminus at Chicago. The Pittsburgh, Fort Wayne & Chicago Railway Company is the outgrowth of a consolidation of several railroads effected on August 1, 1856. The line into Chicago was opened in 1858. The Pittsburgh, Cincinnati, Chicago & St. Louis Railway Company is the result of many consolidations and reorganizations. The original company, known as the Chicago & Cincinnati Railroad, completed its road between Chicago and Logansport in the spring of 1861.

The Wabash Railroad is an extension of the Old North Cross Railroad, the first and only one of the many projected lines that was ever finished and operated by the state of Illinois. The construction of the property was begun in 1838.

The more important railroads now operating in Chicago may claim place among the city's oldest institutions. They have not, in any large sense, intruded themselves into the heart of an established city; they occupied their present locations when the city began. Their activities have stimulated other activities of the city and as the city has grown they have grown and have developed with it.

In 1850, two years after the Galena & Chicago Union Railroad began operation, Chicago had a population of 30,000, grouped chiefly about the mouth of the Chicago River. Even as late as 1864, when the number of railroads had multiplied, the population of the city was less than 170,000. The railroads, when they entered Chicago, naturally established themselves near the center of the city's population, that is, near the mouth of the Chicago River. As time passed the railroads continued to occupy the sites granted them in earlier days. In the beginning they located their yards outside of the limits of the town where low-priced land could be had. In process of time, however, the city expanded, industrial establishments increased, residences multiplied, and the railroad yards which originally were outside of the city became surrounded by improved property. This growth of the city and the prosperity it implied further augmented the business of the railroads. More cars were handled and more yard room became necessary in which to handle them; again the railroads reached back into the country for unoccupied areas upon which to develop; and here also they were in time enveloped by the growing city. This process has been repeated so many times that the appearance of a map of present-day Chicago suggests that wherever a railroad has chosen to marshal its cars, there the city has ultimately crowded in. The process has been a perfectly normal one. The railroads have been an impelling force which has aided in the city's legitimate development.

These are matters which, under the pressure of present-day conditions, are naturally enough sometimes overlooked or forgotten. For example, there are many who feel that the Illinois Central Railroad established itself in its present location contrary to the public desire. Such a feeling is without foundation in fact. The record shows that the company did not voluntarily elect to locate its lines on the lake front, but was forced to do so by a mandatory ordinance passed by the City Council of Chicago.

Examining this phase of the question with greater fidelity to its historic details, it may be noted that on September 20, 1850, the Congress of the United States set aside a grant of land for the building of the Illinois Central Railroad from Chicago to Mobile, through the states of Illinois, Mississippi and Alabama. The bill providing for the construction of the road under this grant was passed by the Illinois legislature in February, 1851, and was accepted by the railroad company in March of the same year.

The southern limits of the city of Chicago at that time were at 22d Street. In applying for admission to the city, the railroad company, through Robert Schuyler, its first president, requested that it be allowed to enter the city along the west bank of the south branch of the Chicago River, and to extend its line along the river to Kinzie Street, where it could connect with the Galena & Chicago Union Railway (now the Chicago & North Western), which was coming in along the west side of the north branch of the river. Under this plan the freight terminals of the Illinois Central Railroad would have been located on the west side of the river. The plan proposed by President Schuyler, however, was not viewed with favor by the property owners along the east side of the river, who wanted the railroad to come in adjacent to their holdings. A situation soon developed which made the matter of securing a location of the line into the city one of considerable delicacy for the railroad promoters. In the summer of 1851, Mayor Gurnee of Chicago went to New York for a conference with the board of directors of the railroad company with a view to inducing them to locate the road on the lake front. There was one reason why many desired the railroad to be built there, of which few are now aware. At that time the waters of Lake Michigan were constantly making attacks on the shore line. A large expense had been incurred by the city and by property owners along Michigan Avenue in the construction of shore protection, which, after completion, proved entirely inadequate. In 1849 a small assessment was levied for this work, and by 1851 the sum of $12,000 had been expended in shore protection under the direction of the Superintendent of Public Works. In the fall of that year a storm so seriously damaged the shore protection that the residence of Mayor Gurnee at the corner of Michigan Avenue and Monroe Street was menaced with destruction. The popular feeling at the time was reflected by articles in the daily press, which clearly indicated a desire on the part of the people and the city officials to have the

Illinois Central locate on the lake front and assume the responsibility of providing the much needed shore protection.

The officers of the railroad company, yielding to the importunities of the Mayor, the arguments of the public press and the sentiment of an apparent majority of the City Council, finally accepted the Mayor's suggestion, and ordinances were prepared by officials of the city for carrying it out. The first four ordinances proposed by the city were rejected by the railroad company. It is noteworthy, however, that all of them specifically provided that the railroad should enter along the lake front and should construct a breakwater from Randolph Street to the southern limits of the city sufficient forever to protect the city from the wash of the lake. The ordinance finally accepted by the railroad company was passed July 14, 1852.

The construction of the breakwater was commenced in September, 1852, and completed in 1854. Thereafter the city had no trouble from the encroachment of the lake. Prior to 1860 the railroad had expended approximately $500,000 for lake front protection work.

It is evident from this brief review of the facts that the Illinois Central is located along the lake shore because the city designated this site as the one which it preferred that the railroad should occupy. It is not unlikely that the detailed history of the development of other railroads within the city of Chicago would sustain, with equal justice, the right of the railroads in the possession of the sites upon which their facilities and tracks have been built.

1.10 Chicago's Fuel Resources: The city of Chicago possesses a great natural resource in an abundant fuel supply near at hand, lying in the vast coal fields of Illinois, Indiana and Western Kentucky, and forming what is known as the Eastern Interior Coal Basin. The extent of these coal fields is indicated by fig. 5.

The major portion of the basin is situated in Illinois, underlying 86 counties and covering an area of about 35,600 square miles, or about 65 per cent of the entire area of the state. The eastern portion of the field extends into Indiana, underlying an area of about 6,500 square miles distributed over 26 counties, in 18 of which coal is produced on a commercial scale. The southeastern portion of the field extends into Kentucky, underlying 11 counties along the northern border of the western part of the state and embracing an area of about 6,400 square miles.

The United States Geological Survey gives estimates for the entire Eastern Interior Coal Basin, of the original amounts of coal available, the amounts exhausted and the amounts now available for future supply. These estimates are presented as table XXXVIII.*

Though generally distributed over all except the northern part of the state, a considerable number of the beds in the part of the field lying in Illinois are of limited extent or thickness, and under present conditions are commercially unsatisfactory as sources of fuel supply. The first Illinois Geological Survey determined that there were 16 different coal-beds in the state, and numbered them consecutively. Calculations made by A. Bement in 1909† indicated that of the total output from the state, coal No. 6 (Herrin, Belleville, etc.) produced 59 per cent, coal No. 5 (Springfield, Harrisburg, etc.) yielded 25 per cent, and coal No. 2 (LaSalle, Third Vein, Wilmington, etc.) produced 12 per cent. The remainder, 4 per cent, was mined from No. 7 (Danville), No. 1 (Rock Island) and from other seams.

In the eastern part of the field, in Indiana, the coal-beds show remarkable persistency over large areas. They vary from three to ten feet in thickness, a majority of the mines having seams five feet or more in depth. Block and semi-block coals, so-called because of the almost perfectly rectangular blocks into which they break, are found along the eastern edge of the field. They occur in basins some of which are but a few acres in area. In many of these basins the veins vary in thickness from several feet at the center to a few inches at the edges.

Cannel coal is also found at one or two points in the eastern part of the field, and in the southeastern part there are two beds of excellent coking coal.

Briefly, all the coals of the Eastern Interior Coal Basin are bituminous and, compared with

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* Report of the United States Geological Survey, "Mineral Resources of the United States," 1911.

† Bulletin No. 14, Illinois State Geological Survey, 1910.

FIG. 5. EASTERN INTERIOR COAL BASIN

their principal market competitors, are relatively high in sulphur, ash, moisture and volatile matter. They are generally free-burning and non-coking. Their sulphur content limits their direct use in metallurgical processes and tends to complicate the problem of storage. Their high volatile content tends to make them produce smoke when burned, a tendency, however, which may be overcome in many classes of service. Their ash content is relatively high. The quality of the coal appears to improve with the depth of the seams, and there is generally an improvement in quality from north to south.

TABLE XXXVIII. UNITED STATES GEOLOGICAL SURVEY STATISTICS RELATING TO THE EASTERN INTERIOR COAL BASIN

State	Area Square Miles*	Estimated Original Supply Tons	Production 1911 Tons	Total Production Through 1911 Tons	Total Exhaustion Through 1911 Tons	Estimated Available Supply Tons
1	2	3	4	5	6	7
Indiana	6,500	44,169,000,000	14,201,355	219,180,709	328,000,000	43,841,000,000
Western Kentucky	6,400	36,241,000,000	7,111,737	98,264,971	147,000,000	36,094,000,000
Illinois	35,600	240,000,000,000	53,679,118	844,012,353	1,266,000,000	238,734,000,000
Totals.....................	48,500	320,410,000,000	74,992,210	1,161,458,033	1,741,000,000	318,669,000,000
United States†	310,296	3,076,204,000,000	496,221,168	8,739,572,427	14,181,980,000	3,062,022,020,000

* Known to contain workable coal. † Includes colliery consumption.

Coals from the southern part of the field have, as a rule, a higher heating value per unit of weight than coals from the northern part.

The coals of the Eastern Interior Coal Basin are tributary to Chicago. They are Chicago's coals and she must use them. In certain classes of service the problem of burning them smokelessly is not a difficult one. In other classes of service certain factors must be made the subject of further study.*

1.11 Evidences of Public Interest in Smoke Abatement: One of Chicago's present-day problems of significance is that of smoke abatement. Progress in smoke abatement in Chicago is urgent, because presumably the population of a world-city is interested in bringing it about. It is a difficult problem because the city's fuel consuming industries sustain the activities of a great community, and any procedure in smoke abatement which unduly restricts fuel consumption, injures industry, or interferes with the orderly procedure in transportation, will, in the complexity of the city's life, affect adversely the interests of many people.

A large proportion of the fuel consumed in Chicago consists of bituminous coals which are to be regarded as relatively smoky. Interest in smoke abatement has been the natural outgrowth of the use of such fuels. Evidences of such interest early appeared in individual communications to the public press; in public addresses; in papers presented to technical societies; in resolutions adopted by various clubs; and in active campaigns undertaken at intervals by the press of the city for the purpose of keeping the matter before the public.

Forty years ago (in 1874) there was organized a "Citizens' Association" having for its object the promotion of public welfare. It undertook to determine some of the legal aspects of the problem of smoke prevention, and to aid smoke inspectors in their work by assisting in the prosecution of the more conspicuous offenders. The first formal recognition of the authority of the municipal government to exercise control in this matter found expression in an ordinance of the City Council, which was passed in April, 1881.†

Voluntary organizations of citizens were formed just prior to the Columbian Exposition of 1893, notably, "The Society for the Prevention of Smoke," having for its purpose primarily the improvement of the city's appearance during the exposition period. The work undertaken was that of educating consumers in correct methods of burning soft coal. The society organized and maintained a strong technical staff. Its expenses were borne entirely by subscription. At the conclusion of the World's Fair its activities ceased.

In 1904, the Municipal Art League's Committee on Smoke Prevention submitted a report urging the enforcement of the law. "Every citizen who sees a chimney habitually smoking should be a voluntary inspector, and register complaints at the City Hall. Public opinion can be expressed by personal condemnation of smoke offenders."

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* See chapters 101 and 105; also Bulletin No. 15, University of Illinois, "How to Burn Illinois Coal Without Smoke," by L. P. Breckenridge, 1907.

† The text of this ordinance is given in chapter 102 of this report.

In 1908, the Hamilton Club addressed letters to the officers of railroads operating in Chicago, asking for an expression of opinion regarding the electrification of those roads. The replies while varying in detail generally expressed the view that the art of electrification was still in an experimental stage and that the expense involved would be too great in view of the uncertainty of compensating returns.

In 1908, also, a report on "The Electrification of Railway Terminals," with the subtitle, "As a Cure for the Locomotive Smoke Evil in Chicago, with Special Consideration of the Illinois Central Railroad," was prepared, under the direction of the Mayor and the Committee on Local Transportation of the City Council, by a special committee appointed for the purpose.* In this report of 350 pages the committee subdivided the results of its study as it had subdivided its work, the several chapters appearing as separate articles. The subjects investigated and the several experts responsible for their development were as follows:

The Harm of Smoke . . .	Dr. W. A. Evans
The Prevention of Smoke in Chicago	Paul P. Bird
The Railroads as Smoke Producers	G. E. Ryder
The Possibility of Smokeless Steam Locomotive Traction .	G. E. Ryder
Anthracite Coal and Coke as Remedies	Paul P. Bird
Electrification as a Remedy, with Special Consideration of the Illinois Central	H. H. Evans
The Railroads in Relation to Local Transportation .	Milton J. Foreman

The questions which this committee sought to answer, and the conclusions reached with reference thereto, are concisely set forth. The report as a whole represents a systematic effort to place before the people of Chicago the facts, as they were then understood, concerning the important questions the committee had been appointed to study.

A year later, in 1909, the Chicago Association of Commerce, an organization devoted to the welfare of the city and in a peculiar sense representative of its business interests and of its citizenship, undertook the direction of an educational movement in the abatement of smoke and has since persisted in its efforts.

1.12 The Work of the Chicago Association of Commerce: At a meeting of the executive committee of the Chicago Association of Commerce, held October 29, 1909, Pres. Edward M. Skinner reported the formation of a committee of eight to consider the subject of the electrification of railroad terminals in the city of Chicago. The committee was constituted as follows:

John M. Ewen, John M. Ewen Co., Chairman; W. L. Abbott,† Commonwealth Edison Co.; Bion J. Arnold, Consulting Engineer; A. Bement, Consulting Engineer; Paul P. Bird, Chief Inspector Department of Smoke Inspection; W. F. M. Goss, College of Engineering, University of Illinois; Wm. B. Jackson, D. C. & Wm. B. Jackson; and C. E. Merriam, Department of Economics, University of Chicago.

This committee was requested to consider and report upon questions relating to the desirability and practicability of electrifying the steam railroad terminals in the city of Chicago as a remedy for the alleged nuisance accompanying the use of steam locomotives, as well as upon questions relating to the elimination of smoke in general from the city. The purpose of the report was that of informing members of the Association of Commerce and the public generally upon the subject.

The report of the committee was submitted on July 8, 1910, to Homer A. Stillwell, the President of the Chicago Association of Commerce, and copies were transmitted to the members of the executive committee with a view to the consideration of the report at a subsequent joint meeting of the Board of Directors, the Executive Committee and the special committee which conducted the investigation. The report of the committee in full is as follows:

"CHICAGO, *July 8, 1910*

TO THE PRESIDENT OF
THE CHICAGO ASSOCIATION OF COMMERCE:

Your committee appointed to consider and report upon questions as to the desirability and practicability of the electrification of steam rail-

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* The members of the special committee which prepared this report were Milton J. Foreman, Chairman, Committee on Local Transportation, City Council; Dr. W. A. Evans, Commissioner of Health; Paul P. Bird, Smoke Inspector; G. E. Ryder, Department of Smoke Inspection; H. H. Evans, Mechanical Engineer.

† The record does not indicate that Mr. Abbott attended the meetings of the committee and the final report does not bear his signature.

way terminals in the City of Chicago, as a remedy for the nuisance accompanying the use of steam locomotives, as well as to the elimination of smoke in general from the city, would state briefly, that it finds electrification of terminals to be both practicable and feasible. It recommends that immediate measures for its accomplishment under proper and reasonable plans be adopted.

It is also recommended that until electrification has been accomplished, anthracite coal and coke be used as locomotive fuel.

Your committee considers the problem of smoke prevention in the City of Chicago to be a very serious one, deserving of much more attention than has thus far been given it, and requiring that the present organization of the Smoke Department be materially enlarged.

The conclusions reached by your committee are presented in five abstracts, which are followed by correspondingly designated chapters, in which the several features are discussed in detail.

(1) *Public Demand for Electrification*

While the demand for electrification is based generally on a desire to eliminate smoke, dirt, noise and noxious gases, there is, without doubt, another important reason, not well defined or generally appreciated, which has an unconscious influence. This is a feeling that electric service is more convenient, comfortable and modern than steam service.

(2) *Practicability of Electrification*

Electrification of Chicago railway terminals is a large undertaking and one which cannot be carried into effect in its entirety in the immediate future. But there should be no great difficulty in its successful accomplishment within a reasonable time. Therefore, in the opinion of your committee, electrification is not only practicable, but will be of great advantage to Chicago, including the railroads, and it is recommended for execution under reasonable and proper plans.

The work could probably best start with the electrification of the suburban and other passenger service of several of such railroads as have a dense traffic, and should eventually be extended to all passenger, freight and switching service within the city limits.

(3) *Attitude of Railways toward Electrification*

It would appear that many railway officials expect that eventually electrification will come about through a gradual process of evolution, yet there is no general disposition on the part of the roads to consider the matter in reference to its present or future applications. It is, no doubt, felt by many officials that they are not justified in recommending the consideration of a scheme demanding so large an investment as would be required and one appearing to some of them as embracing many unsolved problems.

There is also definitely expressed opposition on the ground that the use of electricity is not as safe as that of steam. There is, where proper precaution is taken to install sufficient safeguards for life and limb, no reason for such opinion other than that, with all new appliances or mechanical apparatus, until employes become familiar with their duties, there are possibilities for accident, which disappear when the men are accustomed to their work. With electric operation there is no reason for anticipating any greater danger to passengers and employes than with steam.

(4) *Temporary Substitutes for Electrification as an Aid in Smoke Suppression*

While it appears necessary and desirable to bring about the electrification of all railway trackage in Chicago at as early a date as practicable, a considerable time at best will elapse before this can be effected. During the interval this committee would recommend that anthracite coal or coke be used as fuel in steam locomotives, as a temporary solution of the problem prior to and during progress of the work of electrification.

(5) *The Complete Elimination of Smoke in Chicago*

Aside from that produced by locomotives, a large volume of smoke is given off by other fires, and it is practicable to eliminate this smoke. To this end several detailed recommendations are made, the most important of which is enlargement of the scope and the facilities of the Department of Smoke Inspection, also the extension of the inspection service to the full 24 hours of the day, including Sundays and holidays.

DETAILED DISCUSSION OF CONCLUSIONS PRESENTED IN FOREGOING ABSTRACT

(1) *Public Demand for Electrification*

Your committee recognizes the existence of a widespread public desire in Chicago to have all railway terminals within the city limits electrified. It understands that this feeling is based upon a realization of the fact that through the electrification of its railroads much of the smoke which now pollutes the city's atmosphere will disappear, and much of the noise and dirt incident to the present operation of steam locomotives will be eliminated. Your committee, however, recognizes the fact that the railroads are not the only makers of smoke, dirt and noise, and that their complete electrification within the city limits would not of itself suffice to make Chicago smokeless. Your committee agrees that, taken as a whole, the railroads are to be classed among the more conspicuous smoke producers and that smoke from steam locomotives, since it is discharged into the atmosphere at no great distance from the ground and is trailed over long courses, is especially objectionable to the public. While, therefore, it is perfectly natural that the problem of smoke suppression as it presents itself to the public should be assumed to begin with the railroads, the fact as stated above, that they combined constitute but one principal offender, should not be overlooked.

It is, however, probable that the elimination of smoke, dirt and noise are not the only incentives which influence public opinion. That in addition to these, there is an undefined and little recognized factor that has considerable weight. This is a general feeling that electric service is more modern, desirable, and, like electricity for light, more in accordance with present standards of comfort. This influence may be designated as the factor of public appreciation, for which, as yet, no definite value has been determined.

(2) Concerning the Practicability of Electrification

There should be little difficulty arising from any lack of technical knowledge in electrifying all railways entering the City of Chicago. While no enterprise of equal extent has thus far been undertaken, and while it is certain that, in the development of so large an enterprise, a considerable amount of pioneer work would need to be done, the most comprehensive plans need involve no greater problems than have previously been solved elsewhere, or functions which are not now being performed in some part of our country. There are questions as to details to be settled, but these are common to progress in every growing art. The difficulties of carrying out such an undertaking are in fact not mechanical but financial. The initial cost of electrification is high and no company would desire to undertake it unless it could see a fair chance to receive a reasonable return from the necessitated additional investment. Such return must be derived either from reduction in operating expenses, from an increase in traffic, from increased terminal capacity, or from all these combined.

Conditions which are most favorable to the profitable electrification of railway lines are those involving a dense traffic which will permit frequent and regular movement of trains, or those where terminal capacity under steam operation has become congested and inadequate. The passenger service of some of the steam railways entering Chicago presents conditions favorable for electrification. If this service were not operated in conjunction with freight service, it could be said, without question, that it could be more economically performed through electrification. But upon the Chicago lines the passenger service is interwoven with the freight traffic and switching service. Terminal facilities, repair shops and organizations of men serve all classes of service, so that the precise gain which would result from the electrification of the passenger branch of the service alone is not easily determined. Nevertheless, it is the belief of your committee that the electrification of practically all passenger service, which at present is steam operated, would not affect unfavorably the interests of the railway companies concerned, and consequently that even compulsory electrification of such service, if brought about through provisions which would permit its gradual accomplishment, would constitute only a temporary hardship and would ultimately result in a real benefit to the railway companies involved.

The proposition to require all the railroads of Chicago to operate electrically all their service within the city limits constitutes quite another question. The extent of such an undertaking would be comparable in magnitude to the great work of track elevation, which has been proceeding in Chicago for the past seventeen years. In New York City, where, as is commonly known, a great work of electrification has been successfully accomplished, the undertaking, so far as the electrical features are concerned, is of much less magnitude than that of electrifying all the railways of Chicago, although the total cost, including the collateral investment made feasible by electrification in New York, might be comparable with the cost of electrification in Chicago. The electrification in New York was developed to meet the requirements of a situation more serious than that which exists in Chicago. In the case of the New York Central and the New York, New Haven & Hartford railways, entering the city largely through a tunnel, difficulty of ventilation and volume of traffic had made steam operation impracticable. In the case of the Pennsylvania railway the development of a new passenger terminal made it necessary for trains to pass through long tunnels in which it was undesirable to employ steam locomotives. This development was therefore stimulated by conditions, the urgency of which exceeds that of any claim which can be put forth by the citizens of Chicago. Electrification in New York has been applied only to locations where the density of traffic is great. The cost also has been large. Notwithstanding its cost, this electrification is not only successful from an operating standpoint, but promises to be financially successful also. While all the work in the electrification of railways which may hereafter be undertaken will profit by experience already gained and by so doing may secure for itself some saving over the costs of previous undertakings, such savings are problematical and are likely to be largely, if not wholly, neutralized by new embellishments made possible by the progress of the art. Furthermore, the feasibility of realizing such savings in the near future is not sufficiently evident to warrant withholding electrification for their realization and doing without its advantages in the meantime.

Your committee recognizes the fact that any scheme of electrification for Chicago which is not comprehensive, and which does not include all classes of service of all railways, will fail to satisfy the public expectation. Notwithstanding this expectation, however, it is considered that the attitude of the public and the city government should show the same consideration as that displayed in the track elevation work, which has not only conserved the interests of the public but of the railways as well.

(3) *Attitude of Railways toward Electrification*

The advantages of improvements, such as track elevation in Chicago, the adoption of air brakes and automatic couplers, were recognized by many railway officials, but their general adoption was reluctantly accepted owing to the financial difficulties involved. Air brakes and automatic couplers were, however, found to be appliances of such value in the handling of trains as to now make it appear strange that their adoption should ever have been opposed. But while their employment was for the purpose of reducing accidents and the loss of life, it was found that they were of large economic advantage to the railroads, making not only the operation of trains more convenient and safe, but also adding to the capacity of their trackage and equipment. Similarly, where electrification has been adopted by steam railways, greatly increased capacity has resulted.

Track elevation in Chicago was brought about to satisfy the public demand for reduction in number of casualties at grade crossings. Possible benefit to railroads other than this received no consideration, and the public felt that the work would necessarily be a burden which the roads must carry. It has been found, however, that track elevation has been of sufficient economic advantage to the railroads to justify the investment required for its creation; thus, judging from all precedents, it is reasonably certain that electrification, although at present considered a formidable undertaking, is an improvement, which, like the things before mentioned, will prove to be of economic value to the railroads, and also that, as with them, its application will necessarily be brought about by pressure of public demand.

(4) *Temporary Substitutes for Electrification as an Aid in Smoke Suppression*

Assuming that electrification is urged chiefly as a convenient means for reducing smoke, questions naturally arise as to whether some substitutes for it can be employed at smaller cost. The railway companies operating within the limits of the City of Chicago, in their endeavor to make steam operation less objectionable, have proposed and to some extent are now using for their locomotives various forms of carefully selected fuel. Your committee recognizes the fact that the general use of anthracite coal or of coke for locomotives would eliminate smoke, but the use of coke would not only be accompanied by an increase in the solid material now discharged from the locomotive stacks but would also involve other disadvantages from an operating standpoint. It would not, however, reduce the noise incident to present methods of operation nor would it diminish the volume of furnace gases discharged nor reduce their effect in vitiating the atmosphere. These are the only fuels insuring smokeless operation which in the present state of the art can be used commercially in steam locomotives. The so-called "smokeless" or low volatile varieties of coal are smokeless only to the extent of being less smoky than local coal. Fuel oils when used in locomotive fire-boxes constitute no guarantee of smokeless combustion.

The general adoption of any specially selected fuel for use in Chicago is by no means a simple matter. The use of anthracite coal or coke, for example, will greatly increase the cost of fuel to railways making the change. Such fuels can be used successfully in a locomotive fire-box, but they cannot be handled with the same facility as the bituminous coal now used. The use of anthracite coal or coke within the City of Chicago will make it necessary either to employ the same fuel over an entire division, one end of which is in the City of Chicago and the other end a hundred miles or more away, or the existing divisions must be cut in two by the establishment and maintenance of locomotive terminals just outside of the City; in either case the cost of operation will be increased.

From its study along these lines it appears to your committee that no practice depending upon the use of specially selected fuels in existing forms of steam locomotives can ever make railway operation within the City of Chicago as acceptable to the public as that which can be secured through electrification; that all use of such fuels is in fact to be regarded as a mere palliative, the general adoption of which is to be encouraged and vigorously urged notwithstanding the increased cost entailed, as useful in meeting the present emergency, but as in no sense constituting a substitute for electric operation.

The preceding discussion has concerned itself with means which may be employed to suppress smoke in the operation of modern locomotives. The possibility of applying to the modern steam locomotive smoke preventing devices designed to permit the use of coal tributary to Chicago railroads without developing smoke is in the present state of the art a process of great uncertainty, and one which in locomotive operation, unless locomotives are re-designed upon an entirely different basis, is entirely secondary in importance to the efforts of a well-trained fireman working without such means. Whether the future will result in the development of some type of motor involving the use of internal combustion engines of such power as to be capable of handling the traffic of the City of Chicago as a substitute for the present steam locomotive, and whether such motors, if made available, will perform the service as satisfactorily and at as low a cost as it can now be performed by electric locomotives, are entirely matters of speculation.

(5) *The Complete Elimination of Smoke in Chicago*

The complete electrification of Chicago railway terminals would not suffice to make the city smokeless. It has been estimated that only from 30 to 50 per cent of all the smoke which pollutes the atmosphere of Chicago comes from locomotives. The remainder is from domestic and industrial fires, small and large. Large industrial fires may, through the use of appliances which are well known, readily be made smokeless, and it is to fires of this class that the City Smoke Department has given most attention. A large percentage of the total smoke comes from domestic fires or from industrial fires so small as to make difficult the bestowal of sufficient care upon them to secure the prevention of smoke. Any plan, therefore, which aims at the development of a smokeless city must deal effectively with such small fires. Interpreting this problem, in terms of Chicago's fuel resources and our present knowledge of the art, requires a very strict enforcement of City ordinances not only for the suppression of smoke from equipment already installed, but very stringent regulations governing installation of new furnace apparatus. With the present administration of the Department of Smoke Prevention, under the direction of a competent commission, it is probable that a new and better ordinance than that now in force could be of limited value at the present time, but the future will impose requirements not dealt with at present.

While the policies and methods at present employed in the conduct of the Department of Smoke Inspection are, without doubt, correct in a general way, there are several matters that should receive particular attention, as follows:

a. Much smoke is produced at night, on Sundays and holidays, when the city smoke inspectors are not at work. As this smoke is fully as objectionable as the smoke made during other times, the immediate establishment of smoke inspection service during these periods is recommended.

b. When an enlarged organization of the Department has been effected, the ordinance should be changed to deal with different grades of smoke instead of dense smoke only, as at present.

c. The small heating boiler used in apartment houses, small flat buildings and residences is a very crude appliance. The state of the art in its application to apparatus of this character is in the same undeveloped stage as that of the standard type of boiler furnace years ago, and its development has remained stationary while that of the power boiler has made great advances. Therefore, the development of improved types of low pressure heating boilers should be encouraged and within reasonable time their use made compulsory.

d. The use of such smokeless fuels as gas and coke should be encouraged. Each is an ideal fuel for domestic and small intermittent fires. The only limitation to their employment is that of cost and anything that will reduce that cost should be encouraged.

e. The extension of the plan for supplying steam for heat and power to adjacent buildings from a plant centrally or conveniently located with reference to those to be served, is a scheme having great possibilities for the elimination of smoke, as it makes possible the generation of steam under more favorable conditions than prevail in small plants.

f. The installation of automatic stokers in the smaller steam power plants should be enforced.

g. As there appears to be no way of operating river tug boats without objectionable smoke except by the use of anthracite coal, the boats on the Chicago River should be required to use such fuel.

h. Passenger and freight steamers in the Chicago River should either be required to use a better grade of fuel than at present, or mechanical stokers should be installed to use the fuel now employed.

i. There are many special problems in connection with the prevention of smoke that have and will present themselves from time to time, requiring special and particular study. Such problems consist in the suppression of smoke from furnaces of rolling mills, brickyards, malleable iron plants, terra cotta works and in similar industries, as well as from automobiles, etc.

In conclusion your committee would summarize the results of its deliberations, regarding electrification, as follows:

a. That it is practicable from an engineering standpoint.

b. That when effected it will be of economic advantage to the railroads.

c. That it will present no greater element of danger to passengers and employes, if properly installed, than now exists with steam operation.

d. That the most serious and difficult feature of the problem is the financial one.

With reference to the general smoke problem, your committee considers that it is a larger and more serious one than realized by the general public. Also that its solution justifies an increase in the facilities of the Department of Smoke Inspection.

Respectfully submitted,

John M. Ewen,

Bion J. Arnold,

A. Bement,

Paul P. Bird,

Wm. B. Jackson,

W. F. M. Goss,

C. E. Merriam.

The report having been received by the President of the Association of Commerce, a joint meeting of the Board of Directors, the Executive Committee and the special committee on Smoke Abatement and Electrification of Railroads was held on August 19, 1910, for the purpose of considering its findings. Several members of the special committee which formulated the report responded to questions and enlarged upon certain features of it. The consensus of opinion expressed at the meeting was to the effect that no definite action should be taken upon, nor publicity given, the report until copies had been furnished to those railroads which were members of the Association, and an opportunity thereby afforded their delegated representatives to take up the various features of the report with the Association and with the special committee, the purpose being to ascertain the views of the railroads.

Pursuant to the sentiment of the meeting of August 19, 1910, and in accordance with a formal resolution to that effect, a conference was held on September 22, 1910, at which the Board of Directors of the Association of Commerce was represented by 13 members, the Executive Committee by 9 members, exclusive of those who were also members of the Board of Directors, and the railroads operating in Chicago by 15 general officers representing 15 railroads. At this conference emphasis was laid upon the fact that the report was based upon the opinions of individual members of the committee and that the committee was in possession of no information not available to others. The desirability of a thorough investigation was discussed and the Association was assured that the railroads would co-operate with it in carrying out such an investigation.

The results of this conference were reported to the Board of Directors of the Association at a meeting held on December 1, 1910, at which time, however, it was announced that the city of Chicago had proposed a commission to investigate the question of electrification without reference to the matter of smoke abatement. An interchange of views between officers of the Association and Mayor Busse of the city led to the adoption by the Board of a resolution tendering the services of the Association to the Mayor in respect to any plans involving the formation of a commission and offering to aid him in the work contemplated.

This may be considered the conclusion of the work of the first committee of the Chicago Association of Commerce. Subsequent action of the Board of Directors looked to the formation of a joint committee representing the Association and the city.

1.13 The Organization of the Present Association of Commerce Committee of Investigation on Smoke Abatement and Electrification of Railway Terminals: In accordance with the resolution of the Board of Directors of the Association of Commerce at a meeting held on December 1, 1910, as outlined in the preceding section, the following letter was approved at a meeting held on December 13, and was sent to Mayor Busse and the City Council on that date:

CHICAGO, *December 13, 1910*

TO THE HONORABLE MAYOR
AND THE CITY COUNCIL
OF THE CITY OF CHICAGO, ILLINOIS:

GENTLEMEN:

The Chicago Association of Commerce believes that the question of electrifying the steam railway terminals and trackage within the limits of the City of Chicago is worthy of a comprehensive analysis by experts acting under the direction of an impartial Civic Commission or Committee.

Through one of our Special Committees we have, for eighteen months, studied one phase of the subject, and have now reached a point where it seems necessary to go into the practical or business side of the question, involving among other things the element of cost.

We desire to co-operate with the City in this work, and therefore suggest that his Honor, the Mayor, name four persons whom we will be glad to add to our Committee. The contemplated work will be done without expense to the City and the results thereof will be turned over to the City.

Respectfully yours,

THE CHICAGO ASSOCIATION OF COMMERCE,
HOMER A. STILLWELL, PRESIDENT

At a meeting of the Board of Directors on January 6, 1911, the following reply was read:

CHICAGO, *January 6, 1911*

THE CHICAGO ASSOCIATION OF COMMERCE,
CHICAGO, ILLINOIS.

GENTLEMEN:

This is to certify that on the 19th of December, 1910, his Honor, the Mayor, with the concurrence of the City Council, appointed Col. Milton J. Foreman, Mr. T. E. Donnelley, Dr. W. A. Evans and Mr. Paul P. Bird, as additional members of the Committee of your Association in the matter of the Electrification of Steam Railway Terminals, as suggested in your communication of December 13, 1910, addressed to the Mayor and City Council.

(Signed) Francis D. Connery,
City Clerk.

The communication was referred to the incoming Board of Directors, to accept the appointment of the persons named as members of the Association's Committee on Electrification.

At a meeting of the Board of Directors on January 28, 1911, the chairman stated that the plan which was submitted to the Mayor before the matter was referred to the Association, provided that funds should be furnished by the railroads in order that competent engineers could be employed. He asked for permission to continue negotiations to this end, as it had not yet been determined what amount of money could be expended. It was clear that the Association could not use its own funds for this purpose.

The Board instructed the president to continue the negotiations.

On February 27, 1911, a conference was held at which the presidents of seven railroads were present. The whole situation was discussed, and consideration was given to the question of the expense of a comprehensive investigation by experts. The results of this conference were reported to the Executive Committee on March 3, 1911, when the announcement was made that the railroads had agreed to pro-rate among themselves the expense of an impartial investigation to be made under the auspices of the Association of Commerce. It was stated that the commission to undertake the work would comprise the four members named by the Mayor, four to be named by the railroads and nine to be selected by the Association of Commerce.

On March 17, 1911, the President of the Association announced the personnel of the Committee as follows:

Named by the Mayor

Dr. W. A. Evans, Commissioner of Health

Paul P. Bird, Smoke Inspector

T. E. Donnelley, R. R. Donnelley & Sons Co., Chairman Smoke Abatement Commission, City of Chicago

Milton J. Foreman, Attorney-at-Law, Chairman, Committee on Local Transportation, City Council

Named by the Railroads

W. A. Gardner, President Chicago & North Western Railway

H. G. Hetzler, President Chicago & Western Indiana Railroad

Darius Miller, President Chicago, Burlington & Quincy Railroad

C. E. Schaff, Vice President New York Central Lines

Named by the Association of Commerce

W. F. M. Goss, Dean of the College of Engineering of the University of Illinois

E. R. Graham, D. H. Burnham & Company

Richard C. Hall, President Duck Brand Company

Jesse Holdom, Attorney-at-law

Frederick H. Rawson, President Union Trust Company

Harrison B. Riley, President Chicago Title & Trust Company

John W. Scott, Carson, Pirie, Scott & Company

Francis T. Simmons, President Francis T. Simmons & Company

Mason B. Starring, President Northwestern Elevated Railroad

These nominations were formally confirmed by the Association of Commerce.

The Committee thus appointed organized on April 1, 1911, by electing Jesse Holdom, Chairman, T. E. Donnelley, Vice-Chairman, and Frederick H. Rawson, Secretary.

At a subsequent meeting (April 28, 1911) the scope of the proposed investigation was, on recommendation of a subcommittee, defined as follows:

1. A determination as to the necessity of changing the motive power of steam railroads to electric or other power.
2. The mechanical or technical feasibility of such change.
3. The financial practicability of such change.

> These general topics naturally subdivide into various channels for investigation, but your committee is of the opinion and so reports, that these subdivisions should be determined as the investigation proceeds, by the chief engineer in charge, and that the order in which such investigation shall proceed be determined by the chief engineer, subject, however, to further direction of the Committee.

The following presidents of the Association of Commerce became *ex officio* members of the Committee during their respective terms of office: Harry A. Wheeler in 1911; E. U. Kimbark in 1912; Howard Elting in 1913; Joseph H. Defrees in 1914; and Charles L. Dering in 1915.

At different periods Messrs. Schaff and Starring withdrew. J. J. Bernet was appointed to succeed C. E. Schaff and Harry A. Wheeler succeeded Mason B. Starring.

On May 26, 1914, Mr. Rawson resigned as a member of the Committee and as secretary. Norman H. Davis was appointed secretary *ad interim* and Howard Elting was appointed to succeed Mr. Rawson as a member of the Committee. Mr. Elting resigned January 8, 1915, and he was in turn succeeded by Joseph H. Defrees.

Darius Miller died August 23, 1914, and was succeeded by Hale Holden, September 22, 1914.

On April 14, 1911, Horace G. Burt was elected to the office of Chief Engineer and assumed his duties on May 1. To him was assigned the complex problem of outlining the work of assembling and organizing an expert staff which should be capable of conducting the various researches to be undertaken. Mr. Burt had few precedents to guide him, for no community had ever before set itself to such a task with an equal conception of its magnitude and an equal desire to leave nothing undone which could add to the value of the proposed work. The staff was organized as follows:

HORACE G. BURT	Chief Engineer
L. H. EVANS	Terminal Engineer
HUGH PATTISON	Electrical Engineer
THEO. H. CURTIS	Mechanical Engineer
JAMES WALKER	Assistant Engineer
GIBBS & HILL	Consulting Electrical Engineers
GEORGE R. HENDERSON	Consulting Mechanical Engineer
BENJ. C. BURT	Editor
NORMAN H. DAVIS	Secretary

Mr. Burt died May 19, 1913, and on June 29, 1913, W. F. M. Goss was elected to fill the vacancy. There has been no cessation of work since the beginning. Changes in the staff have taken place from time to time and minor details of investigation contemplated in the original conception have been omitted; but the general plan as formulated by Mr. Burt has been followed.

In the fulfilment of its purpose the Committee has sought:

> 1. To conduct a comprehensive study of the causes and effects of atmospheric pollution in the city of Chicago and to determine the extent to which steam locomotives contribute thereto.
> 2. To present a summary of facts upon which electrification, if entered upon, must be justified, assuming such a course to be technically and financially practicable.
> 3. To present such facts as tend to show the advantages and disadvantages of complete electrification and an estimate of its cost.

In the accomplishment of this purpose, the Committee has met monthly or oftener for a period of more than four years. It has had the assistance of many different agencies, among the chief of which may be mentioned the railroad officials of Chicago. The results of the Committee's labors are to be seen in the facts presented by this report.

PART I

THE NECESSITY FOR THE ELECTRIFICATION OF CHICAGO'S RAILROAD TERMINALS

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101. SMOKE ABATEMENT IN LARGE CITIES, DOMESTIC AND FOREIGN

SYNOPSIS: This chapter presents a review of literature relating to smoke and smoke abatement. It seeks to reflect the history of smoke abatement since the time when smoke first was regarded as objectionable. It constitutes a world view of the development and of the present state of the art of smoke abatement.

Efforts to reduce the smoke of cities have manifested themselves both in legal prohibitions and in measures designed to educate firemen, owners of furnaces and the general public with reference to desirable means to be employed in reducing smoke.

Various mechanical devices for aiding combustion, for disposing of smoke and for reducing its effects are described. The feasibility of dispensing with certain sources of smoke is discussed. The effects of smoke upon health, vegetation and material objects are shown to be matters upon which there is much diversity of opinion. Attempts to evaluate them have not been entirely successful.

THE LITERATURE OF SMOKE ABATEMENT

101.01 **The Committee's Review of the Literature of Smoke Abatement:** As an initial step in the development of its researches, the Committee has reviewed with care the published records of investigations relating to smoke abatement which have been made by scientific commissions and professional experts in this and other countries. It has translated a voluminous file of foreign documents. The various papers and reports which have thus been brought together may be assumed to present a world view of the history and progress of smoke abatement.* Any attempt to reduce this mass of material to the limits of a few pages presents great difficulties, but it is believed that the account which follows reflects with reasonable accuracy the important facts of the more extensive record and that it will serve to give a broad view of the general problem which confronts Chicago.

Smoke and soot are generally regarded as modern evils attending the rapid industrial development of the nineteenth and twentieth centuries, but they are not so in fact. Our first definite information of the use of coal in Europe is gained from complaints which were registered against it as a nuisance. In England in the time of Edward I (1272–1307) the nobility protested against the use of "sea-coal," as bituminous coal was

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*Archives of the Committee, Vols. M 1 to M 5. For list of the authorities consulted, see Appendix, section 701.59, Bibliography.

called to distinguish it from charcoal, and in the reign of Edward II (1307–1327) a man is said to have been put to torture in London because he had filled the air with "a pestilential odor" through the use of coal. On the continent complaints arose almost as early. In 1348 at Zwickau in Germany the town authorities proclaimed as law: "Know ye that all smiths working within the walls shall refrain from the use of coal in their work." From those early days down to the present, the consumption of bituminous coal has, however, continued, though constant efforts to suppress or restrict its use have been made.*

The earliest scientific treatise in English on smoke abatement seems to have been a small volume addressed to King Charles II in 1661 and published by his express command, entitled, "Fumifugium; or the Inconvenience of the Aer and Smoak of London Dissipated: together with some Remedies Humbly Proposed." The author was the famous diarist, John Evelyn, one of the founders of the Royal Society. A few years later, in 1686, a Mr. Justel read before the Philosophical Society, "An Account of an Engine that Consumes Smoke," and in 1716 Dr. Desaguliers, a Fellow of the Royal Society, published an octavo volume entitled, "Fire Improved: being a New Method of Building Chimnies so as to Prevent their Smoaking." Toward the end of the eighteenth century many scientific and practical men, including the distinguished engineer James Watt and the ever active Benjamin Franklin, devoted their thought to different problems arising from the use of bituminous coal for domestic and industrial purposes.

Modern methods of investigation applied to smoke abatement may, however, be said to date from 1819, when the British Parliament appointed a Select Committee to study and report upon it. Since then there have been innumerable discussions and investigations, and the mass of reports and printed matter has grown with great rapidity. These are, of course, of varying value, but there are many which deserve careful consideration.† The main phases of the general subject which have been discussed include:

1. The effects of smoke upon health and comfort, upon vegetation, and upon architecture, sculpture, fabrics and other material objects.
2. The means, mechanical and legal, of decreasing these effects by preventing or diminishing the emission of smoke.
3. The nature of smoke, its polluting effect upon the atmosphere, smoke formation and the measurement of smoke.

Many of the discussions are merely sentimental, and even where scientific aims and methods have prevailed, positive and definite results are generally meager. Probably the topics best understood include the nature of smoke, its formation and the mechanical means of preventing it, but even on these points opinion is not unanimous. Of the effects of smoke upon animal life, plants and inanimate objects, of the nature and extent of pollution of the air by smoke, and even of the modes of smoke estimation, the basis for positive and accurate judgments is less in evidence, although the existence of a strong popular sentiment against smoke cannot be denied. The contrast which appears, for example, between the frequency and vehemence with which smoke is denounced and the amount of experimental or statistical evidence as to the effects of smoke upon human health, is rather striking. A large part of the literature bearing upon these important topics is found, when carefully examined, to consist of mere conjecture, of repetitions of the conjectures of others, of expressions of instinctive antipathies, or of opinions expressed merely for immediate effect and unsupported by competent evidence. Numerous detailed observations, experiments and analyses have yet to be made before the general subject of smoke abatement can be said to have attained a truly scientific form. This fact not only appears from a general survey of the literature of smoke abatement, but is distinctly announced by some of its ablest investigators. The literature shows that the problems involved have attracted the attention of men of eminence in engineering, in medicine, in law, in biology and in practical affairs, a fact which more than justifies their careful review.

101.02 Definitions of Smoke: Two conceptions of smoke have prevailed, one, which regards it, to use the words of Dr. Johnson's Dictionary, as

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*In England, Richard II (1377–1399) laid a tax on coal ships, and Henry V (1413–1422) appointed a commission to oversee the importation of coal into London. Under Elizabeth the use of coal was prohibited during the sessions of Parliament.

†E. H. McClelland, "Bibliography of Smoke and Smoke Prevention." Mellon Institute Smoke Investigation, University of Pittsburgh, Bulletin No. 2, 1913.

"the visible effluvium or sooty exhalation of anything burning"; another, which takes account of the invisible as well as of the visible constituents. The former is the older conception and represents even today the view popularly entertained. No matter how great a volume of invisible gaseous products of combustion may be sent forth by a chimney, the chimney, in common parlance, is said not to smoke so long as it emits no visible exhalation. Modern dictionaries and cyclopedias, taking account of this, usually add to the old definition some such statements as the following: "Hence, sometimes, technically, any such incompletely burned volatilized product, whether visible or not";[*] "in its more extended sense, the word 'smoke' is applied to all the volatile products of combustion which consist of gaseous exhalations charged with minute portions of carbonaceous matter or soot."[†] A German investigator of air pollution, Wolpert, gives perhaps the most exact and inclusive definition of smoke by describing it as "the products of combustion diffused in air."

101.03 Smoke as Defined by the Ordinances: In general, the prohibition of smoke ordinances relates to smoke in its visible aspect. The New York City, Toronto, Minneapolis, Denver, Des Moines and Milwaukee ordinances prohibit "dense smoke." In Baltimore, it is "black or dark gray smoke"; in Knoxville, "dense black or dense gray smoke"; in Springfield, Mass., "dark smoke or dense gray smoke"; in St. Louis, "dense black or thick gray smoke"; in Winnipeg, Toledo, Indianapolis, Richmond, Ind., and Reading, Pa., "dense black or gray smoke." In the cities of Great Britain, it is "black smoke"; in Paris, France, "black, thick, and continuous smoke"; in the cities of Germany, "smoke containing soot in visible quantities." In a few ordinances, for example, those of Buffalo, Cleveland, London and Munich, "noxious gases or vapors or offensive odors" are prohibited and recent British legislation has specifically included "mineral grit." The Philadelphia ordinance attempts greater precision by specifying "smoke intercepting more than 60 per cent of light, and fumes of sulphurous or noxious odor." In Yonkers, N. Y., the ordinance prohibits "smoke, cinders, dust, gas, detrimental or annoying to any persons not engaged on the premises."

Obviously, the terms by which objectionable smoke is defined in the smoke abatement ordinances are not precise. In many cases they have been found too elastic to enable proper enforcement of the ordinance. A comprehensive definition of smoke must take account of the process by which smoke is produced, the nature and composition of its constituents, the manner in which these may be diffused in the air and the degree to which they may, separately or collectively, be regarded as injurious.

101.04 The Formation of Smoke: The factors affecting smoke formation, as usually set forth by the literature of the subject are:

1. The combustible (fuel or substance burned).
2. The supporter of combustion (air).
3. The temperature at which combustion proceeds.

The composition of the various kinds of fuel is too extensive a subject for present discussion. It must suffice to note that the combustible elements in coal may be grouped into two divisions, namely, volatile matter and fixed carbon. The proportion of these varies greatly. In anthracite coal the fixed carbon is relatively high and the volatile combustible low. In bituminous coals the carbon content is lower and the volatile content higher.

As a supporter of combustion, air may be regarded as composed of oxygen and nitrogen in proportions approximately as follows:

	PER CENT	PER CENT
Oxygen	by weight 23 . .	by volume 21
Nitrogen	" " 77 . .	" " 79

Oxygen is the component of air which is actively concerned in combustion, but indirectly nitrogen is of importance. Since combustion is a chemical process in which a definite weight of oxygen unites with a definite weight of the so-called combustible, it is clear that, for complete combustion, air must be supplied in sufficient quantity to provide enough oxygen to unite in proper proportion with all of the combustible. Moreover, the air must be intimately mixed with the combustible so that the oxygen may reach and unite with every particle of it. Theoretically there must be, for every pound of carbon, 2.67 pounds of oxygen or 11.55 pounds of air. In ordinary furnace practice, however, it is necessary

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[*] The New International Dictionary.
[†] The Imperial Dictionary.

to provide for more than the theoretical amount of air. This is due to the fact that not all of the oxygen present can be used, because of imperfect mixing. Some oxygen, therefore, is present in the stack discharges.

In regard to the third factor in combustion, namely, the temperature, a few elementary principles only can be stated. Every combustible has its "critical temperature" below which it will not unite with oxygen, that is, will not burn. The premature cooling of the gases of a furnace will suppress the process of combustion. Too great a supply of air tends to reduce the temperature of a furnace, and under certain conditions, tends to hinder combustion. The presence of the nitrogen leads to the absorption of heat and to lower furnace temperatures, with the result that air sustained combustion always proceeds at a lower temperature than the combustion of a similar fuel in the presence of oxygen alone. The literature touching the importance of air regulation in its relation to that of temperature regulation is extensive.[*]

101.05 The Process of Combustion: The eminent English mechanical engineer, the late Bryan Donkin,[†] writes that "notwithstanding all that has been said and written about the process of combustion, the actual way in which the chemical constituents of coal separate and recombine is still rather uncertain." Without attempting to make a complete summary of all that has been written concerning combustion, the following may be noted as representing a generally accepted view as presented by the literature on the subject.

Combustion of bituminous coal proceeds by stages. There is first a period, occurring at a comparatively low temperature (about 500 degrees Fahrenheit), of "destructive distillation" so-called, in which a disruption in the substance of the fuel takes place, the volatile portion being thrown off and separated from the non-volatile. The volatile portion is described as consisting of tarry vapors, or hydrocarbons, compounds which in themselves are subject to further decomposition. The second stage of combustion involves the decomposition of the hydrocarbons and the burning of their gaseous constituents at a temperature of about 800 degrees Fahrenheit. This stage is a critical one as regards smoke formation. If too little air is admitted to the furnace, or if the amount admitted is not properly distributed, a portion of the carbon in the fuel is carried away unburned and visible smoke results. If too much air is admitted, local cooling often occurs. Smoke may also be formed if the gases are permitted to come in contact with cool surfaces, such as the tube surfaces of a boiler, thereby checking the process of combustion. Again, if the motion of the gases towards the chimney is rapid there may not be sufficient time for the proper mixing of the air and the combustible, and smoke may appear as a result of this incomplete process. The third stage of combustion proceeds at a temperature which is normally above 1600 degrees Fahrenheit. It is during this stage that the non-volatile portion of the fuel, consisting chiefly of carbon, is burned. This third stage of combustion may easily be made "smokeless"; but, if the supply of air be deficient, incomplete combustion and visible smoke may result.

The degree of thoroughness attending the process of combustion is often described as either "perfect" or "imperfect," "complete" or "incomplete." Combustion is regarded as "complete" when all the combustible components of a given fuel are consumed, and as "incomplete" when such combustible components are only partially consumed. In the case of a fuel composed entirely of combustible material, however, combustion will proceed with results different from those which appear in the case of a fuel containing an incombustible constituent. In the latter case there will be a residue, though the combustible material in the fuel may be burned as "completely" as in the first case. According to Prof. Orme Masson,[‡] combustion is "complete" when its products consist simply of water vapor, carbonic acid, nitrogen and sulphurous acid. This definition has reference to the combustion of a fuel composed wholly of combustible materials. Another authority[¶] says that theoretically the products of complete combustion are carbonic

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[*] For example, Lov and Haier; see also "The Aims and Work of the Hamburg Smoke Abatement Society," by E. Nies, Chief Engineer, 1912.

[†] "Heat Efficiency of Steam Boilers," Chapter IX, 1898.

[‡] "Smoke," Encyclopædia Britannica, Ninth Edition.

[¶] "Suppression radicale de la fumée et la récupération de ses éléments." (The Complete Suppression of Smoke and the Recovery of its Elements.) Moniteur industriel, Vol. 30, p. 327, 1903.

acid, water vapor, azote (nitrogen), besides a minimum amount of ash. This definition would apply in the case of most ordinary fuels, except that these contain sulphur, which is in part incombustible.

Professor Masson specifies that the products of "incomplete combustion," in addition to those of complete combustion above named, include hydrogen, hydrocarbons, carbonic oxid and unburnt carbon in a very finely divided state. These products, he says, constitute smoke in the proper sense of the term. But, according to the second authority above quoted, the products of incomplete combustion constituting smoke are:

1. Solid particles—soot, charcoal, dust, ashes.
2. Visible gases—tar and water vapor.
3. Invisible gases—carbonic oxid, hydrogen, hydrocarbons, nitrogen, carbonic acid and other negligible elements.

Donkin points out that "some authors insist on a distinction between smoke, or the condensed unburnt tarry vapors, and soot which is practically carbon forming the residuum after the hydrogen has been burnt off"; and it is true that many authors speak of "smoke and soot" without implying that it is possible practically to distinguish between them. Donkin himself, while rejecting this distinction, seems to separate smoke proper from the flue-gases present in combustion whether complete or incomplete.

From the foregoing it seems that the products of "complete combustion" may be regarded as practically invisible, while those of "incomplete combustion" are or may be visible. This distinction cannot be applied literally, however, in making smoke observations, since, under certain conditions of draft, ash may be drawn through the stack and when emitted may be visible. Such visible products of "complete" combustion are necessarily regarded as smoke. Again, certain products of "incomplete" combustion are known to be invisible, and it may easily happen that a product of incomplete combustion appearing in the furnace as visible smoke may become so diluted with air or steam before leaving the stack as to present to the observer an impression of smokelessness.

Probably the only positive test of the completeness of combustion is that which involves an analysis of the discharges resulting from the process. If these are found to contain no combustible elements the combustion may be accepted as complete.[*]

An important aspect of combustion relates to the economical use of fuels, which is a matter that cannot be completely separated from that of smoke prevention. As a result of elaborate tests made in recent years[†] it has been determined that, under certain conditions resulting in apparent smokelessness, there may be an escape of unburned combustible gases with a consequent loss of heat units, while conditions which may utilize fuel values to a fuller extent result in a slight degree of smokiness. Careful laboratory tests have demonstrated, however, that the amount of heat lost in "black smoke" is comparatively insignificant, one investigator[‡] reporting that "under the worst possible conditions of combustion, if the smoke were collected there would be a saving of only 14.7 pounds from a ton of coal, provided all the smoke were burnt again."

Summarizing the preceding statements, it appears from the literature[¶] dealing with combustion and with the relationship between the process of combustion and the production of smoke that:

1. Though the ordinary definitions and usages of the term "smoke" have reference chiefly to its visible aspect, it has invisible constituents which, in many respects, are as important as the visible. A full understanding of the effects of smoke, and the means to be employed to abate it, must encompass both its visible and invisible aspects.
2. "Complete" and "incomplete" as applied to combustion are relative terms and do not denote processes having entirely different and opposed results. Complete combustion does not always eliminate visible smoke nor does incomplete combustion always produce visible smoke.
3. Among the products of combustion, whether "complete" or "incomplete," are to be found certain non-combustible constituents. Obviously, the abatement of these cannot be brought about merely by efforts to control the process of combustion.

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[*] D. T. Randall, H. W. Weeks. "The Smokeless Combustion of Coal in Boiler Furnaces." U. S. Bureau of Mines, Bulletin 40. 1912. For a table showing the varying relations between carbon dioxid and fuel consumption, see Barr's "Combustion of Coal and Prevention of Smoke," 1904.

[†] F. Haier, "Die Beziehungen zwischen der Rauchentwicklung und der Ausnutzung der Brennstoffe und die Mittel und Wege zur Rauchverminderung im Feuerungsbetrieb." (The Relation between the Development of Smoke and Utilization of Fuel and the Ways and Means of Abating Smoke in the Working of Furnaces.) Zeitschrift, des Vereines Deutscher Ingenieure, Vol. 49, pp. 20, 83, 167, 1905.

[‡] B. P. Flory, "Test of the Amount of Combustible in Smoke." Sibley Journal of Engineering, Vol. IX, 1894–95.

[¶] In the Bibliography of the subjects covered by this chapter which is presented in the Appendix, section 701.59, will be found many references which will prove interesting to those who wish to follow, in greater detail, the discussions of the preceding sections.

101.06 Smoke Inspection: Immediately on being discharged from the stack, smoke becomes an object of concern to the city smoke inspector. The literature of the subject shows that it has generally been assumed that the nuisance of smoke is in proportion to its "visible density." Some account of the various methods that have been in use for determining the "density" of smoke as it appears at the top of the stack or chimney will be of interest. The controlling conditions are:

1. The requirement laid down by the ordinances under which inspection proceeds, as to the character of non-permissible smoke, as "black smoke" or "dense smoke." *
2. A standard by which to estimate the so-called "black" or "dense" smoke.
3. The means and methods by which smoke observations may be made and recorded.

The number of degrees of color or "visible density" distinguished in the different scales employed as standards of measurement has ranged from 2 to 10. One of the earliest, if not the earliest, of the official scales contained 10 degrees of color, including white and black, the degrees being expressed, not by name or number, but by specific diagrams. This scale was used by English experts in tests made in 1819 for a committee of investigation. About 1845 there came into use in Manchester, England, for the purposes of ordinary city smoke inspection, a scale of 3 degrees, "no smoke visible," "moderate smoke," "dense smoke." In 1860, in a smoke test of a steamship, 2 degrees were employed, "light brown smoke" and "dense black smoke." At the smoke abatement exhibition of Manchester and South Kensington, England, in 1881–82, a scale of 10 degrees was employed, evidently under the authority of the First English Smoke Commission, the work of which was done during the period of the exhibition. Naturally, the object sought in this case, as in the investigations of 1819, was to classify the performance of various furnaces rather than to ascertain whether the simple requirement of a city smoke ordinance as to density of smoke was violated or not. The Second English Smoke Commission, in 1895, employed a scale of 3 units, "faint," "medium" and "dense." In Germany, at about the same time, a commission adopted a scale of 5 degrees. In Switzerland a scale of 6 degrees has been used.

Several means have been employed to eliminate the purely personal factor in the application of any standard. One of these consisted of series of printed diagrams of different shaded areas corresponding to the different shades of smoke. With these diagrams before them at the time smoke was being examined, it was assumed that stack observers could hardly fail to report correctly the shade of smoke observed. Another means was that of photographing the smoke observed or of photographing, at a single exposure, the smoke observed and the standard of measurement. Glass plates of different shades, presenting an obstruction to light corresponding to that of the smoke observed, have also been found useful as standards of measurement.

Each of the means previously mentioned has been found to possess its peculiar defects, at least for the purposes of accurate comparison or practical use. A uniform and permanent coloring or shading of diagrams has been found difficult to duplicate. Photographs have been found to vary when developed under different conditions, and the shades of colored glass plates are subject to apparent variation when used by different observers. It remained for Professor Ringelmann of Paris to produce a logical and easily duplicated standard of measurement. The Ringelmann scale consists of 6 areas of equal size which may be drawn in black ink on white paper or cardboard. The first area is outlined only; its surface is white. The sixth area is entirely black. The intermediate areas are subdivided into small squares by crossed lines, the width of the lines and their spacings being such as to blacken a definite portion of the area. The first area (white) is designated as O, or zero smoke.† The second area is drawn so that 20 per cent of its surface is covered by black lines. This represents No. 1, or 20 per cent smoke. The third area has heavier lines which cover 40 per cent of the total surface, and this represents No. 2, or 40 per cent smoke. The remaining areas represent, respectively, No. 3, or 60 per cent smoke, No. 4, or 80 per cent smoke, and No. 5 (black) or 100 per cent smoke.‡

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* See account of the kinds of smoke prohibited by city ordinances, section 101.03.

† See translation of Professor Ringelmann's essay in La revue technique, June 25, 1898, Archives of the Committee, Vol. M 3.

‡ For an illustration of the Ringelmann scale and for suggestions concerning its application, see section 105.02.

As these diagrams may be produced correctly by anyone, there need be no uncertainty as to the exact shade of blackness denoted by the number of the scale. This chart has been in use for more than a decade in France, England and the United States, and has been generally adopted by cities as the official standard of smoke inspection. Professor Ringelmann, having designed this chart not merely for the purpose of smoke observation but for the purpose also of determining actual degrees of smoke, combined with the table of degrees of smoke density a table of co-efficients by means of which, the time duration of smoke emissions of the various densities being given, the degree of the nuisance might be calculated. The following is Professor Ringelmann's table of co-efficients:

SMOKE	CO-EFFICIENT
No. 1	1.0
" 2	2.8
" 3	5.2
" 4	8.0
" 5	11.2

To illustrate the application of these co-efficients, let it be supposed that smoke of density No. 3 is emitted for two minutes; then we have 2 x 3 x 5.2, or 31.2, as the degree of the nuisance committed. Of course, a number of such calculations would generally be combined in determining fully the extent of a given nuisance. These co-efficients, however, have not been received with the same favor as have the charts, and, in fact, do not seem to be employed at all in estimating smoke nuisances in the cities. The Ringelmann scale as a means of measurement, however, is now very generally used and the assumption seems to be that its use furnishes a satisfactory index to the amount of "nuisance" resulting from the emitted products of combustion. This assumption, however, has often been questioned, for the simple reason that the scale serves merely for measuring visibility, while smoke is known to include invisible as well as visible constituents. The necessity of employing still other means to determine the extent of the nuisance arising from smoke will soon be recognized. The literature of the subject reveals no satisfactory measure which comprehends all the qualities of smoke in a single value.*

101.07 Composition of the Atmosphere: The atmosphere of large cities is a complex mixture of numerous substances. The well-known gaseous constituents normally found in the atmosphere of cities include oxygen, nitrogen, carbon dioxid and water vapor. Hydrocarbons, solid particles, and compounds of nitrogen, chlorin, sulphur and carbon are also found in varying quantities. Rare gases such as argon, helium, neon, krypton, xenon and ozone are often present, but as a rule only in small quantities.

The properties of the several constituents of air are set forth in the following paragraphs.

Oxygen is essential to animal life and to combustion. Although enormous quantities of it are consumed, the proportion found in the air remains almost constant. Normal dry air contains about 21 per cent by volume of oxygen. Under abnormal conditions, as in mines after a fire, in dry wells or in caves the proportion of oxygen may be less. While animal life is adjusted to thrive to best advantage on the normal proportion of 21 per cent, it can adapt itself to conditions under which the percentage of oxygen takes a wide range. Haldane, an English authority on mine air, states that when the amount of oxygen falls as low as 10 per cent a person exerting himself will notice its lack. When the proportion of oxygen falls as low as 7 per cent, the mind becomes confused and muscular power is impaired. A further decrease causes loss of consciousness. Pure oxygen may be inhaled for some time without noxious effect, in fact, pure oxygen is frequently used as a restorative. Many investigators have determined the exact proportion of oxygen in samples of atmospheric air, and the variation from the normal proportion of 21 per cent by volume has been found to be so slight as to cause no effect upon the human organism. Recent analyses of the air of the New York Subways yielded so slight a variation in the amount of oxygen that the routine determination of oxygen was omitted from subsequent tests. A recent authority states that uncontaminated air has a constant oxygen content irrespective of conditions of weather or season.

Nitrogen as a component of atmospheric air is almost as important as oxygen, although its properties are entirely different. While oxygen is active, nitrogen is inert and combines with but

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* Some original investigations along this line have been undertaken by the Committee and are elsewhere reported, chapter 105.

few substances. Nitrogen effects a dilution of the oxygen. Respired air contains practically the same percentage of nitrogen as normal air. Nitrogen has no physiological action, but is an essential constituent of the atmosphere in that it serves the purpose of decreasing the activity of the oxygen. It neither burns nor supports combustion. It constitutes about 78 per cent by volume of the air under nearly all conditions.

Water vapor is one of the variable constituents of the atmosphere. Its effect upon life is largely mechanical. In a cold damp atmosphere, one feels colder than in a dry atmosphere of the same temperature, because the water vapor aids the air in conducting heat away from the body. In a warm dry atmosphere, one feels cooler than in a damp atmosphere of the same temperature because the evaporation of perspiration is much more rapid when the atmosphere is dry than when it is moist. The amount of water vapor in the air determines its relative humidity. When the air contains all the water vapor it can hold at a given temperature it is called saturated, and its relative humidity is 100 per cent.

Carbon dioxid, a combination of carbon and oxygen, is ordinarily present in the atmosphere, but in variable amounts. Joseph Black of Edinburgh is given credit for having, in 1757, first determined its presence in atmospheric air. It is a product of combustion. It results from any process in which carbon or any substance containing carbon is burned. It is one of the products of decaying organic matter and it is exhaled from the lungs of all animals. It results also from numerous industrial activities as, for example, the burning of limestone to form quick lime. Notwithstanding the multiplicity of its sources, the percentage found in normal atmospheric air does not vary greatly. Two factors, the action of the wind and the diffusion which takes place in the case of all gaseous mixtures, tend to distribute any slight excess of carbon dioxid from the locality producing it to other localities where vegetation and other agencies tend to assimilate the carbon and free the oxygen. The combination which occurs in combustion is dissolved in stimulating plant growth. The processes are continuous and, in a general sense with reference to the vast atmospheric world, they balance each other. Carbon dioxid like nitrogen does not support combustion. It is non-poisonous, but may become seriously objectionable or even dangerous if present in excessive amounts, since its presence serves to decrease the proportion of oxygen in the atmosphere. The effect on animal life of increasing the percentage of carbon dioxid by small amounts is merely to cause deeper inspiration so that the amount of oxygen inhaled per unit of time may remain constant. Man breathes more than one-half cubic meter of air per hour. Of this volume 21 per cent is oxygen and normally 0.03 per cent is carbon dioxid. The exhalation from the lungs contains approximately 16 per cent oxygen and 3.7 per cent carbon dioxid. It is evident that in confined places, such as public halls, habitations and other places where persons assemble, the percentage of carbon dioxid may progressively increase if proper ventilation is lacking.

The rare gases, argon, helium, neon, krypton and xenon, which are often present in atmospheric air, are not regarded as of sufficient importance to be considered in this investigation. With the exception of argon, which usually constitutes about 0.94 per cent of the air, the proportion of these gases is minute and, for all but the most scientific determinations, negligible. They have no effect upon the human system.

Ozone, a very active gas, is a polymer of oxygen which may be formed by the discharge of electricity through the atmosphere. It is present in noticeable quantities after electric storms. According to Alexander Smith, it is very questionable whether there is any ozone in the air except in the neighborhood of electric discharges or after a thunder storm. It is more active than oxygen but has many properties similar to those of oxygen.

Hydrocarbons, compounds of nitrogen, chlorin and sulphur, and particles of solid matter are present in the air in quantities varying according to local conditions. These substances are sources of atmospheric pollution since they arise from waste products from industrial activities, combustion or decay, or from special or unusual natural phenomena.

Carbon monoxid is also a polluting gas in the atmosphere. It is produced by incomplete combustion of carbonaceous materials. It is one of the substances which frequently render mine air dangerous. It is also one of the constituents of water-gas which is often used for fuel-gas by municipalities. It burns to produce carbon dioxid but does not support combustion. It is poisonous in its effects upon animal life, having about 200 times as great an affinity for the hemoglobin in the blood as oxygen. As little as 0.2 per cent will cause injury to man.

In addition to being present in the free state in the atmosphere, nitrogen is capable of forming compounds the presence of which may indicate atmospheric impurity or pollution. Ammonia, composed of nitrogen and hydrogen, is one of these compounds. It contains no oxygen and does not sustain life nor support combustion. Ammonia is formed by the decay of organic matter containing hydrogen and nitrogen, a process which involves a bacterial action especially in the case of decomposing animal or vegetable matter. Ammonia has an extensive industrial use in various processes, as in the manufacture of ice. Its presence in the atmosphere may, therefore, be due to some accident, or to leakages from industrial plants in which it is used or produced. It may under certain conditions be produced by combustion of fuel. There are few recorded results of determinations by investigators of the amount of ammonia in the atmosphere.

Nitrogen, in the presence of oxygen and under the influence of the electric spark, may form oxids of nitrogen which, with water, form nitrogenic acids. One of these, nitric acid, may be formed by the action of bacteria on certain constituents of the soil.

Chlorin, an element which in itself is not so commonly known, but which is the most important constituent of common table salt, may be introduced into the atmosphere as a result of the combustion of coal, from excreta, from refuse, from laundries (in which it is used for bleaching purposes), from electrolytic plants and from other industrial activities. Chlorin is an element so active that it is always found in combination with some other element. With hydrogen it forms hydrochloric acid, familiarly known as muriatic acid. With sodium it forms sodium chlorid, or common salt, and with ammonia it forms ammonium chlorid, or sal ammoniac. In such combinations chlorin is not harmful to the human system. Its presence in the air simply indicates the presence of some one of these compounds. If it should exist in the atmosphere as hydrochloric acid, a corrosive poison, its action would be injurious to metals and other materials. The acid, however, is a gas and the salts are solids; so that the distribution is dependent upon the character of the compound, and it is very unlikely that it could exist except in some combination. Chlorin found in the atmosphere near the sea coast, for instance, without doubt exists very largely, if not entirely, as sodium chlorid derived from the salt water.

Sulphur may be present in the air in several forms. From organic matter containing sulphur may arise, by decomposition, hydrogen sulphid, the odor of which is observed in decaying eggs. This substance is also present in some mineral waters. Sulphur in coal burns to sulphur dioxid. When oxygen combines with sulphur dioxid it forms sulphur trioxid, which, with water, in turn forms sulphuric acid. Sulphuric acid is very corrosive, attacking and decomposing all sorts of building materials, and is more or less injurious to animal and vegetable life. It is difficult to distinguish the various forms in which sulphur exists in the air, since the total amount of sulphur compounds present is small.

Dust in the air is a subject that has been discussed by many persons. Dust includes solid materials of any kind which may be diffused through the atmosphere. Dust is so variable in character and quantity that a description of all its properties would be beyond the scope of this review.

Environment greatly influences the nature and quantity of the dust in the air. In the country, dust is composed largely of soil, pollen, seeds and similar material. In the city, dust may originate from such sources as street debris, structural material, coal, soot, cinders and ash. In addition to the objectionable features of dust in the atmosphere, it has been stated that each particle of dust arising from localities in which disease exists, may carry many disease germs. The formation of fog is also attributed to the presence of dust in the atmosphere. Aitken has shown that a sudden cooling of air containing solid particles, with the consequent separation of some of the moisture from the air, results in a deposition of the moisture with a dust particle as a nucleus for each drop. These drops of moisture, with the particles of dust in them, when suspended in the atmosphere cause fog. If there is no dust there can be no fog. Humidity doubtless has an important effect upon fog since, if the humidity is high, a slight decrease in temperature will cause precipitation.

The amount of dust or solid matter in the atmosphere has been estimated by two methods, by counting the particles, and by collecting the material and measuring its relative color or weight.

The effects of dust in the atmosphere upon solar radiation is a matter to which investigators have given attention. "All the solar rays that reach the earth penetrate the atmosphere and, in the course of their journey, they are considerably thinned out and modified. Sunlight as it reaches us seems white, but when it leaves the sun it is probably blue and it is the interception and scattering of the blue rays by the air—chiefly by the dust in the air—that gives blueness to the sky and diffuses light. The importance of the dust in scattering and diffusing sunlight is often forgotten."*

The fact has been established also that the composition of the atmosphere has an effect upon the radiation of the actinic rays of the sun. An investigation was conducted in 1894 by E. Duclaux, the results of which are referred to by Ronald C. Macfie as follows: "Duclaux's estimates of the variations in actinic radiation and his explanation of them as due to the presence of more or less organic matter in the air may or may not be correct; both have since been impugned; but the fact remains that actinic radiation is affected in some way by the composition of the air and varies within very wide limits. The importance of this variation will be realized when we remember the varied part played by actinic rays in various chemical processes."

101.08 Country and City Air: It appears that the pollution of city air by smoke is not so much a matter of deficiency in the oxygen content, as of the presence in the air of positive impurities such as the solid and gaseous products of combustion and dust from various sources.

The presence of solid products of combustion in any appreciable quantity may be said to be a characteristic of "city air" as opposed to "country" or "normal" atmospheric air. It is true, however, that, owing to the volitant capacity of dust and soot, the air in the vicinity of cities for many miles around may be impregnated with soot and other products of combustion and with dust from many sources.

Carbon dioxid appears in amounts which are only slightly different in city and country air. On this point Rubner says:† "The values of the difference of carbon dioxid in city and country air are small, very small, if one regards them superficially. . . . Many are completely wrong and expect of impure city air great quantities of carbon dioxid as a result of mixture with smokestack air. . . . The amount of smoke is infinitesimally small and has scarcely any influence on the carbon dioxid content. . . . The changes taking place in the atmosphere of a large city need not comprise a very great increase in the total carbon dioxid content in order to involve a considerable pollution of the air if the hygienic effects are taken into consideration." As to the quantitative difference between the carbon dioxid content of city air and that of country air, it does not, as a rule, exceed 0.01 per cent.

Carbon monoxid, which cannot be said to be a constituent of country air, has been found in minute quantities in city air.

Ammonia, nitrous acid and nitric acid, found in country air only in small quantities, are sometimes much more in evidence in the atmosphere of cities.

Sulphur dioxid and sulphur trioxid, rarely found in country air, are frequent and very active constituents of city air.

The differences just pointed out between city air and country air are not to be assumed as being due entirely to the products of combustion; they may be aggravated by the greater activities of the city as expressed in many different ways.

101.09 The Determination of Polluting Constituents of the Air: The difficulties encountered in determining correctly the nature and amounts of the solid constituents of the atmosphere have been found much greater than those encountered in making determinations of the gaseous constit-

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*Ronald C. Macfie, "Air and Health," New York, 1909.

† "Ueber trübe Wintertage, nebst Untersuchungen zur sogenannten Rauchplage der Grossstädte." (Cloudy Winter Days and Investigations in Regard to the So-called Smoke Nuisance of Large Cities.) Archiv für Hygiene, Vols. 57 and 59, 1906.

uents. The great diversity of materials included under the term "dust" has already been shown. The literature of the subject shows that of the solid constituents of the atmosphere, most attention has been devoted to the products of combustion.

An estimate of the amount of atmospheric pollution due to smoke may be based to some extent upon a study of the contents of smokestacks and chimneys, but such a procedure used as a basis for a study of atmospheric pollution is at best an indirect one. Moreover, it deals with only a part of the problem. It takes no account of the diffusion of the products of combustion in the atmosphere after leaving the stack and therefore gives no direct measure of the extent of the polluting effects produced by the discharged gases. Nevertheless, it will be of interest to note that the constituents of flue-gases have been determined in various ways. The following methods are among those described:

1. To determine the amount of soot, a cardboard or a metal plate of known dimensions may be inserted in the stack for a definite period of time, the conditions of combustion during the time being noted. The soot may be washed off the cardboard or the plate by means of a solvent and its amount determined. From the amount thus collected, the total amount passing up and out of the chimney in a given time may be calculated. This experiment gives some indication of the kind of combustion that has taken place, and furnishes a guide as to the amount of polluting constituents thrown into the atmosphere.

2. By another method, a sample of the gases within the stack may be drawn out by suction and strained through cotton or "glass wool." The "soot" thus caught, consisting of mineral as well as purely carbonaceous particles, may be weighed, compared with a fixed standard or burned to determine its character and heating value.

3. By a third method, "soot" may be precipitated by means of low pressure steam, collected, and the amount and nature of its constituents determined.

4. Smoke drawn from a stack may be passed through a tube containing a known amount of loose cellulose, this being afterwards reduced to a pulp by the addition of a known quantity of water. The resulting color of the pulp may then be compared with a scale prepared for the purpose.

5. The smoke drawn from the stack may be caused to record its color on a moving slip of paper.

6. By means of a photometric apparatus, a beam of light may be sent through smoke drawn from the chimney, and from the effect produced upon the light as compared with a known standard the density of the smoke may be estimated.

A study of polluting constituents of the atmosphere by direct methods has of late yielded interesting results. Some of the methods which are reported may be briefly set forth as follows:

1. A known volume of air (200 to 300 cubic feet or more) may be drawn through a paper filter suitably placed, the resulting color of the filter when compared with that of a standard scale serving to indicate the amount of soot per unit volume of air. (Rubner's Method.)

2. Air containing soot may be drawn through a tube filled with "collodion wool," this dissolved with its deposit in a mixture of ether and alcohol, and the "turbid fluid" thus obtained compared with various standards containing known amounts of collodion and soot. (Hahn's Method.)

3. Two discs of glass, one placed vertically and the other horizontally, may be covered with a thin film of oil to which particles of soot and dust carried by the wind will adhere, the position of the vertical disc being controlled by a vane attached to it. The soot caught in this manner may be removed and ground up in oil. The color of the mixture may then be compared with that of a determined standard. (Liefmann's Sedimentation Method.)

4. Plates of glass may be covered with a coating of congealed blackened rosin to which dust will adhere. The particles arrested may be counted with the aid of a microscope and the relative amount of dust in the atmosphere thereby determined. (Stich-Vörner Method.)

5. Soot and dust may be drawn into a chamber, the air of which is kept saturated with water vapor. Suddenly the pressure within the chamber is reduced by means of an air pump and the air thus expanded cooled below the dew point. The drops of water thus formed and deposited on a small plate of known dimensions within the chamber may be counted with the aid of a magnifying glass. The number of dust particles contained in the air under examination can then be calculated. (Aitken's Method.)

6. The natural atmospheric precipitations of snow and rain may be collected and the soot and dust contained therein filtered, weighed and estimated. (Cohen and many others.)

7. Flakes of soot deposited by the atmosphere may be caught in dishes of known dimensions containing distilled carbolated water.

8. A combination of these various methods has often been employed. As to the value of the two general classes of methods just described, the "filtration" method and the "sedimentation" method, differences of opinion have prevailed, Rubner, Renk and others preferring the method of "filtration," Heim, Liefmann and others that of "sedimentation," while Cohen has used both. It may be noted incidentally that the possibilities as to methods have not been entirely exhausted, and that some improvements have been applied in connection with the Committee's investigation in Chicago, the results of which are hereinafter presented (chapter 113).

In England, a Committee for the Investigation of Atmospheric Pollution* was organized by the London Smoke Abatement Conference of 1912, for the purpose of collecting "reliable data as to the degree of pollution of the atmosphere in different places." In order that results, wherever obtained, might be comparable, a standard rain collecting gage has been devised. A line drawing of this gage is presented as fig. 6.

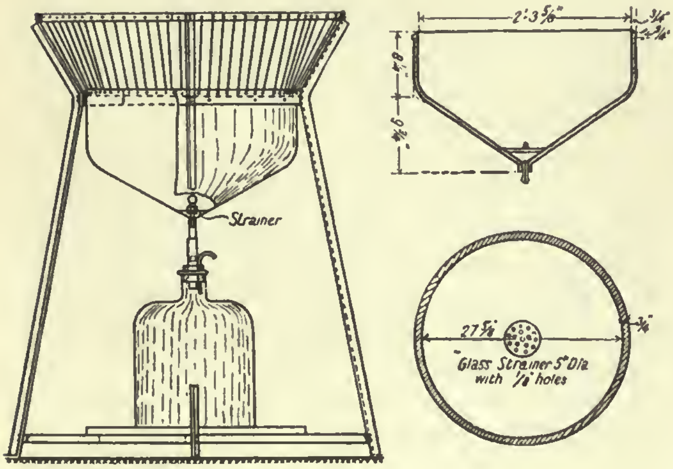

FIG. 6. STANDARD RAIN COLLECTING GAGE. Devised by the Committee for the Investigation of Atmospheric Pollution of the London Smoke Abatement Conference of 1912.

The collecting gage is described as follows:

"The standard gage consists of a galvanized iron stand, supporting a circular enameled iron gage vessel of four square feet superficial area. Projecting above the gage vessel is a wire screen open at the top, intended to prevent birds from settling on the edge of the vessel. The gage vessel is conical at the bottom and communicates, by means of a glass tube and rubber connection, with a group of three or more bottles connected together, designed to hold one month's rainfall. The rain and deposited matter falling on the gage are collected in the bottles and removed once a month for analysis."

Instructions for the use of this gage are as follows:

1. "The gages are to be placed, if possible, on the ground level in open spaces free from abnormal dust.

2. "The bottles containing the water and deposit are to be removed on the last day of each month and replaced by thoroughly cleaned empty bottles.

3. "Before removing the bottles the gage vessel is to be washed down with some of the collected water, a brush and squeegee of standard pattern being used to remove any adherent matter.

4. "A chemical analysis of the water and deposit is to be made by a standard method, details of which will be provided.

5. "A report, on form provided, is to be sent monthly to the offices of the Committee, and a duplicate retained for reference."

Blanks were also formulated to be used in entering observations and in reporting results, the purpose being to assemble the information drawn from many different points.

So great is the care necessary in determining proper surroundings and conditions for collecting "soot" that careful consideration must be given to many factors, among which one authority† includes the following:

1. The character of the receptacle for collecting the soot.
2. Dimensions of the collecting surface.
3. Day and hour of the exposure of the vessel.
4. Place of exposure.
5. Approximate height from the ground.
6. Protection of the point of exposure by walls, buildings or other structures.
7. Sources of smoke in close proximity:
    a. Chimneys of private houses, approximate height.
    b. Chimneys of factories, approximate height.
8. The approximate distance from the point of exposure to the chimneys mentioned.
9. Direction of the chimneys from the point of exposure.
10. Approximate force and direction of the wind during the time of exposure.
11. Average temperature for the day.
12. Barometric pressure.
13. Relative humidity.
14. Day and hour of withdrawing the vessel.

To these points may be added others suggested by Liefmann. The proper selection of a place for making experiments is of the greatest importance. Selections must be made with regard to:

1. The character of the buildings of a city.
2. The positions where the greatest amount of soot, due not merely to local but to diffused smoke nuisance, occurs.
3. The prevailing direction of the winds.

The methods of determining the gaseous elements appearing as polluting constituents of city air are not so varied. They are the processes of the chemist and present no special difficulties. Those which are reported as most often employed in the determination of carbon dioxid are of two classes:

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* Dr. J. S. Owens, Secretary, 47 Victoria Street, Westminster, London.

† Dr. L. Heim, "Nachweis von Russ in der Luft." (Proof of Soot in the Air Archiv für Hygiene, Vol. 27, 1896.

1. Those used by city health departments, which are merely approximate.
2. Those of a more technical nature—chiefly the so-called Pettenkofer method—which are more accurate.

The limit of accuracy of methods of the first class is about one part in 20,000; that of methods of the second class about one part in 100,000. Carbon monoxid determinations are made either by a so-called iodine pentoxid reduction method or by blood test methods, and the results obtained are fairly accurate, the limits being about 25 parts in 1,000,000 for the first method and one part in 100,000 for the second. Ammonia is determined by an acid absorption solution, by methods which are well known. Nitrous acid and nitrites, and nitric acid and nitrates, are determined by means of an alkali solution applied by methods which are common. Sulphur dioxid, sulphur trioxid, hydrogen sulphid and their various salts are determined by methods which employ an alkali or oxydizing absorbent. Sulphur dioxid may be determined volumetrically by means of an iodine solution. Chlorin is determined in the same manner as sulphur.

This statement concerning studies of polluting constituents of air by a direct study of the atmosphere may properly be supplemented by a reference to the Committee's investigations of Chicago's atmosphere (chapter 113).

101.10 Local and Diffused Pollution: A study of smoke in cities should distinguish between a local smoke nuisance and a diffused smoke nuisance. "By the former," says Liefmann,* "we mean a situation in which a single chimney or a few chimneys may pour out a great volume of smoke upon an unfavorably located house. Such conditions can be found everywhere; even in the smallest villages annoyances of this kind are seen although they are much more frequent in large cities, especially in industrial centers. Compared with this, a pronounced case of diffused smoke plague is a phenomenon of a very different character. Here the smoke is not confined to a closely limited area, but we see a whole town enveloped in haze and smoke. A great gray cloud hangs over all; the sun is seen only as through a veil. The strength of its beams is lessened. . . . The essential point in such a diffused smoke nuisance consists in this, that the immense amount of soot diffused through the air is capable, under climatic conditions, of exerting an influence on the meteorological conditions and thus of causing a decrease in the hours of sunshine and an increase in the formation of fog."

Liefmann points out, among other things, that a failure to distinguish between these two classes of smoke nuisance has given rise to erroneous notions as to the smoke nuisance in cities. Legislation with regard to smoke has often been influenced, not by diffused smoke nuisances, but by local smoke nuisances merely. The existence of a diffused smoke nuisance in a city renders the study of air pollution by scientific methods of the greatest importance. The methods used for stack observations are applicable almost solely to a study of local smoke nuisances.

101.11 The Need of Co-operative Study: The need of systematic and comparative studies of the atmosphere of cities is frequently insisted upon in the written discussions of investigators. Rubner says:† "The necessity for further systematic investigation of the atmosphere cannot be denied. The many-sided relations of the atmosphere, of light and of radiation to health are known, at least in their larger aspects, but a definite evaluation or standardization is still lacking. In all directions there is no lack of tasks for workers, but a lack of workers themselves. It has become the custom to introduce every hygienic work with the argument that it is a question of the direct injury to the human body, the disregard of which may result in a number of casualties. Such statements are not always correct; injurious reactions, if to be expected at all, are likely to result only in consequence of long continued injuries such as are manifest to the botanist at least. But injuries, if they occur, are not the less significant because the effect may appear only after months or years. The scientist who would conduct experiments cannot make up for this factor of time; he can only represent long continued injuries by increasing the severity of the injurious factor, a process which leads to many inaccurate results and conclusions. . . . A single

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* "Ueber die Rauch- und Russfrage insbesondere vom gesundheitlichen Standpunkte und eine Methode des Russnachweises in der Luft." (On the Smoke and Soot Question, Especially from the Sanitary Viewpoint, and a Method of Detecting Soot in the Air.) Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, Vol. 40, 1908.

† "Ueber trübe Wintertage, nebst Untersuchungen zur sogenannten Rauchplage der Grossstädte." (Cloudy Winter Days and Investigations in Regard to the So-called Smoke Nuisance of Large Cities.) Archiv für Hygiene, Vol. 59, 1906.

individual is today no longer in a position to carry out such a comprehensive study as is necessary to a full understanding of the question." Others besides Rubner have expressed similar ideas. The broad plan upon which the Committee's researches have been advanced may be accepted as a material contribution along the lines of this general conception.

101.12 Information Concerning the Atmosphere of Foreign and Domestic Cities: Facts of record concerning the atmosphere of various large cities, as presented by the literature of the subject, serve to disclose many features of interest in connection with the present studies. The order in which these are presented has reference to the value of the data rather than to geographical location.

Manchester, England

An extensive study of the atmosphere of the city of Manchester was made as early as 1889 by the Air Analysis Committee of the Field Naturalists' Club of that city. Manchester is a great manufacturing center, situated on three rivers. It has poor natural drainage, a damp soil, a humid atmosphere, and is subject to many fogs. The city is said to have contended with its smoke nuisance for more than three-quarters of a century. Its factories are so located that the central part of the city receives more smoke than any other. The annual coal consumption in Manchester, calculated at 4.14 tons per capita, according to the Official Coal Statement, amounts to about 3,000,000 tons. It is estimated that 44 per cent of Manchester's smoke originates from domestic chimneys, and it is said to contain a large percentage of tarry matter.

On a square mile near Owens College, a suburb of Manchester, more than 1,300 pounds of soot are estimated to have been deposited during a three days' fog. Deposits of black materials, including soot and other solids, were estimated at 26 grains per square yard at Piccadilly near the center of the city, and at 19.3 grains per square yard at Owens College. Deposits of organic matter including soot were found to be greatest during periods of dense fog.

Tests conducted to determine the amounts of carbon dioxid in the atmosphere of Manchester yielded the following results:

	PARTS PER 10,000	
	ORDINARY WEATHER	FOGGY WEATHER
Mean	4.03	6.79
Maximum	6.04	7.34
Minimum	3.11	5.23
On streets, mean	4.03	
In suburbs, mean	3.69	

The variation in the amount of pollution in the air of Manchester at different periods is not apparent from available records. Existing records indicate, however, that air pollution is generally greater in the city than in the outlying districts, and that it is greater in the winter than in the summer.

Manchester fogs are reported to have decreased in number during the past 20 years, but the relation between the decrease observed and the extent of the smoke nuisance is not set forth in a satisfactory manner.

Regarding the effects of smoke on the sunlight of Manchester, the Air Analysis Committee of the Field Naturalists' Club reached certain conclusions, among which the following may be taken as significant:

> 1. November, December and January are by far the darkest months of the year in the city.
>
> 2. The light in the more densely populated districts amounts to about one-half of that in the suburbs during the winter, and less than one-tenth on a moderately bright April day.
>
> 3. The chemical action of the sunlight in the winter months for the suburbs of large cities, as for instance Diddsburg (Manchester) and Kew (London), averages one-third of that for Torquay, in the southern part of England.
>
> 4. Smoke and dampness, which are almost always associated in the city air, absorb an extraordinarily large quantity of the actinic rays of light.

In the following table are shown the number of sunny hours daily at Oldham Road, a Manchester suburb:

	WORK DAYS	SUNDAYS
September	3.41	3.35
October	2.00	2.90
November	0.26	0.16
December	0.13	0.62
January	0.45	0.76
February	1.80	0.28
March	3.03	2.80
April	4.40	8.70
May	5.35	5.00
June	5.24	6.40
July	4.63	3.70
August	3.55	3.90

From this record it is evident that the amount of light on Sundays is, on the whole, only slightly greater than that on week days. The small average number of sunny hours daily seems to afford clearer evidence than does anything else as to the amount of smoke present in Manchester air. From a record of the number of hours of sunshine per year in Manchester, covering a period of 20 years, it appears that the total has decreased in recent years rather than increased.

Leeds, England

Leeds is a manufacturing center. Its annual coal consumption (statistics for 1910) amounts to about 1,500,000 tons. According to Professor Cohen the amount of soot in the air of Leeds may be estimated at about 0.5 per cent of the coal burned, except in the case of domestic coal, where the amount is said to vary from 5.0 to 6.0 per cent. The daily consumption of coal is about 5,000 tons. Based upon the 0.5 per cent ratio, therefore, the daily deposit of soot amounts to about 25 tons. Corresponding figures were obtained by filtering large quantities of air through cotton wool. In 1892 Cohen, by examining samples of snow, estimated the daily deposit of soot at about one-half ton. Determinations were also made by collecting impurities deposited by rain, the results of some of which are presented in the following:*

ASH (PER ACRE)	LB. PER ANNUM
At Leeds Forge Co.'s Works	1,100
SOOT (PER SQ. MILE)	**TONS PER ANNUM**
At Hunslet (industrial)	300
At Leeds Forge (industrial)	250
At Beeston (industrial)	150
At Philosophical Hall	150
At Observatory (non-industrial)	80
TAR (PER ACRE)	**LB. PER ANNUM**
At Philosophical Hall (in town)	80
At Observatory (residential)	32
At Weetwood Lane	25
At Roundhay	14

A greater percentage of tar was found in suburban districts than in industrial districts, the ratio being about 17 to 6.

Cohen and Ruston* present the following table relating to soot in Leeds:

SOURCE	TONS PER ANNUM
Emitted from factories	5,000
Emitted from house fires	30,000
Total	35,000
DISPOSAL	
Blown away	31,480
Deposited temporarily	3,472
Deposited permanently	48
Total	35,000

The number of dust particles, including particles of soot, found in the atmosphere of Leeds ranges from 32,000 to 228,000 per cubic centimeter.

The deposit of sulphur compounds is estimated as follows:

	TONS PER SQ. MILE PER ANNUM
Industrial districts	68.4
Town districts	56.2
Residential districts	39.3
Country districts	23.4

Determinations of chlorin and nitrogen in Leeds rain yielded average results for the three classes of districts in the city and for the country, as follows:

	TONS PER SQ. MILE PER ANNUM	
	CHLORIN	NITROGEN
Industrial districts	44.2	5.19
Town districts	21.4	4.82
Residential districts	16.7	3.45
Country districts	8.7	2.44

The record of sunshine in Leeds, for the years 1891 to 1910, inclusive, shows a slight average increase for the last half of the period. In 1907, the number of hours of sunshine in the center of the city was 1,167, as compared with 1,402 at a point four miles north. Experiments made with an acid solution of potassium iodide showed that the amount of sunlight received at the center of Leeds was about 75 per cent of that received in the suburbs and 60 per cent of that received in the country.

The records of determinations with reference to the extent of the air pollution in Leeds do not represent a sufficient number of observations to render possible a conclusion as to the variation in the extent of the smoke nuisance.

London, England

London's annual coal consumption is estimated (1910) at about 16,000,000 tons. The greater part of London's smoke is generally attributed by investigators to domestic fires.

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* J. B. Cohen and A. G. Ruston, "Smoke: A Study of Town Air," London, 1912. Also A. G. Ruston, "Air Pollution by Coal Smoke and Its Effects on Vegetation." Paper read at the Smoke Abatement Conference, London, March, 1912.

Investigations, extending from June, 1910, to June, 1911, in which "soot-gages" were used, consisting of rectangular hoppers connected to large flasks designed to receive the deposits brought down by rain, were conducted with results as shown by the following table:[*]

SOOT DEPOSIT IN LONDON, ENGLAND,
JUNE, 1910, TO JUNE, 1911

Districts	Rain 4 Sq. Ft. Liters	Total Deposit 4 Sq. Ft. Grams	Insoluble (Soot) Grams	Dissolved Solids Grams	Sulphate SO_4 Grams	Ammonia NH_3 Grams
Buckingham Gate, S. W.	201	71.96	46.23	25.65	6.01	5.01
Horseferry Road, S. W.	192	60.34	33.49	26.85	5.94	5.12
Old Street, E. C.	192	92.51	60.92	31.59	10.96	7.34
Sutton,* Surrey	210	27.90	8.36	19.53	0.90	0.34

Districts	Chlorin Cl Grams	Lime CaO Grams	Insoluble per Sq. Mile Tons	Total Deposit per Sq. Mile Tons	London's Total Deposit Tons
Buckingham Gate, S. W.	5.70	0.37	329	500	38,500
Horseferry Road, S. W.	4.00	0.60	233	420	49,140
Old Street, E. C.	4.04	1.28	426	650	76,050
Sutton, Surrey	2.16	0.29	58	186	

* Sutton is located outside of the city; the remaining points are within it.

From this table it appears that the deposit of soot within the city ranged from 233 to 426 tons per square mile during the year, while outside the city it was 58 tons. The term "soot" as here employed evidently includes not only the solid products of combustion which are discharged into the atmosphere, but also a large amount of matter which cannot be attributed to the combustion of fuel. The composition of soot as determined from samples taken in London and its immediate suburbs is shown in the following:[†]

	CHELSEA (IN CITY) PER CENT	KEW (OUTSIDE) PER CENT
Carbon	39.0	42.5
Hydrocarbons	12.3	4.8
Organic bases	2.0	....
Sulphuric acid	4.3	4.0
Hydrochloric acid	1.4	0.8
Ammonia	1.4	1.1
Oxid of iron	2.6	....
Mineral matter	31.2	41.5
Water	5.8	5.3
	100.0	100.0

The "dust" particles in London air are said to number as many as 400,000 per cubic centimeter. The amounts of carbon dioxid in the air of London are shown by the results of many experiments.

Typical values, expressed in parts per 10,000, are presented as follows:

INVESTIGATOR	YEAR	MEAN	MAX.	MIN.
Smith	1864	3.41	4.28	2.80
	1869	4.39	5.28	3.32
Russell	1882	7.05	14.10	4.50 (Fog)
	1884	4.13	6.40	3.00
Smith	London streets		4.39	
	In country		3.45	

The sulphur content of London atmosphere is reported upon by one investigator,[‡] as follows: "In London about 16,000,000 tons of coal are used per annum directly for heating purposes, and the sulphur content of this coal may range from one to two per cent, giving an annual production of 500,000 to 1,000,000 tons of sulphur trioxid which is diffused in the air." London air contains less sulphur than that of Glasgow and slightly more than that of Manchester. The following facts were found to obtain in London:

1. In clear breezy weather the amount of sulphur dioxid is less than one milligram per 100 cubic feet of air.
2. In anticyclonic periods the amount of sulphur dioxid rises very considerably, and in times of fog as much as from 34 to 50 milligrams per 100 cubic feet of air have been recorded.
3. An increase in the amount of sulphur dioxid is accompanied by an increase in the amount of inorganic impurities in the air.
4. Coal, soot and dust are found to concentrate sulphur compounds; the same is true of rain and snow.

The following comparison of soot and other polluting constituents annually deposited in the cities of London and Leeds, is based on investigations conducted by Professors Cohen and Ruston:

	TONS PER SQ. MILE PER ANNUM LONDON	LEEDS
Soot	58 to 426	25 to 539
Soot, mean	260	220
Sulphuric acid	69	65
Ammonia	51	4
Chlorin in chlorids	26	38

The excess of soot in London could doubtless be attributed to the fact that there is a greater percentage of domestic smoke there than in Leeds, while the excess of chlorin in the Leeds atmosphere may be attributed in part to the influence of sea air and also to industrial activities.

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[*] Dr. H. A. Des Voeux and Dr. J. S. Owens, "Soot-fall of London," Lancet, London, Jan. 6, 1912.

[†] Dr. W. J. Russell, "Town Fogs and Their Effects," Nature, Vol. 23, 1891.

[‡] Dr. Samuel Rideal, "The Acids of Smoke." Journal Royal Sanitary Institute, Vol. 27, 1906-07.

The well-known London fogs are often considered a consequence of smoke and tend to intensify its ordinary effects. The causal relation of coal smoke to fogs in London has been established by observations covering many years, as a result of which it is apparent that any increase or decrease in the number of fogs has paralleled a similar increase or decrease in coal consumption.

In connection with fogs and haze caused by smoke, the amount of bright sunshine in London and other cities, as compared with country localities, has been studied. Values resulting from these studies are presented in the following table:*

SUNSHINE AT LONDON EXPRESSED AS PERCENTAGE OF MEAN VALUES FOR COUNTRY STATIONS

Locality	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec	Year	Loss
Westminster.....	38	45	55	70	82	81	83	86	78	65	46	29	64	36
Bunhill Row	29	42	57	75	88	88	86	85	75	60	38	17	62	38
Kew Observatory	82	75	88	94	100	97	97	97	93	88	85	85	90	10

From an examination of the record of the Royal Meteorological Society, W. G. Russell reached the conclusion that London had, during the five months from November, 1904, to March, 1905, rather less than half the amount of sunshine of the inland stations and little more than one-third of the sunshine of stations on the South Coast.

The utmost importance is often attached to the facts which have been made of record for the city of London, the belief having been expressed that the success or failure of smoke abatement in London is to be regarded as significant in its effect upon smoke abatement as a world movement.

Glasgow, Scotland

The annual coal consumption in Glasgow is estimated (1910) at about 3,250,000 tons. The area of the city is 18.5 square miles. In 1904 the annual "smutfall" was estimated at more than 3,000 pounds per acre; in 1911 the estimated amount was about 4,150 pounds. The estimated annual rate of deposit of soot is higher for the winter months than for the summer months. The increase is attributed to the effect of domestic chimneys, the number of which is said to be about 200,000. According to the corporation chemist of Glasgow, about 120 tons of solid matter in the form of soot and other material are sent into Glasgow's atmosphere every winter day of ten hours from its domestic chimneys alone. The composition of the solid matter of "smutfall," according to the determinations made in 1911, was:

	PER CENT
Mineral matter	65
Carbonaceous	32
Hydrocarbons	3

The total amount of inorganic dust (mineral matter) discharged annually into the atmosphere of Glasgow is estimated to be from 11,000 to 12,000 tons. These results appear to have been based largely upon experiments conducted by the "sedimentation" method, boxes or gages distributed throughout the city having been employed. From the data obtained it is apparent that there has been an increase in the "smut" content of Glasgow air, due to an increased smoke nuisance in recent years. With reference to "dust" particles, as many as 227,944 per cubic centimeter have been found in the atmosphere of Glasgow.

As to the gaseous impurities of the atmosphere, reliable data are lacking. Analyses of air samples disclosed the following averages:

	PARTS PER 10,000
Carbon dioxid, city	5.02
Carbon dioxid, country	3.36

Rideal states that samples of soot contained:

	PER CENT		
	LONDON	MANCHESTER	GLASGOW
Sulphur dioxid	4.60	4.30	7.90
Sulphur	1.84	1.72	3.16

From experiments performed by Cohen and Hefford it appears that about five times as much sulphur escapes in the form of free gas as is contained in soot. This would indicate a large amount of sulphur in the air of Glasgow, larger, in fact, than in the air of London or Manchester.†

From the Royal Meteorological Reports covering a period of five years it appears that the num-

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* R. G. K. Lempfert, "London Fog." Report of Meteorological Council, 1902–1903.

† Peter Fyfe, "Air Pollution in Glasgow and Other Towns in Scotland." Paper before the Manchester Conference of the Smoke Abatement League of Great Britain, November, 1911.

ber of days of fog in Glasgow and the hours of sunshine, per annum, were:

	DAYS FOG	HOURS SUNSHINE
1906	27	1,173
1907	12	1,112
1908	6	1,053
1909	11	1,094
1910	7	1,644
1911	5	1,215

Other Scottish Cities

Reports from 20 other cities in Scotland show that the "mineral" content of air exceeds the carbonaceous content in 13 cities; and that in cities in which the carbonaceous matter was in excess, this condition could be attributed to domestic chimneys. In Coatbridge, a manufacturing city where no smoke ordinance is in effect, the percentage of "smutfall" is much greater than in Glasgow and other Scottish cities.

Hamburg, Germany

Hamburg with its suburbs, comprising an area of 29 square miles and having a population of about 1,000,000, has an average annual coal consumption of nearly 3,000,000 tons. Its coal, unlike that in other leading German cities, is mostly of the smoky variety. In the harbor of Hamburg, one of the leading ports of the continent, smoke is poured forth by many vessels and the prevailing winds carry it over the city. These winds are heavily charged with moisture, a condition which intensifies the effect of the smoke.

In 1908 and 1909 a systematic investigation* with reference to the city's smoke nuisance and air pollution was conducted from four different stations in the city. A summary of the results of this investigation is presented in the following paragraphs.

On the basis of the individual determinations made at the four stations, the soot,† in milligrams per cubic meter of air, varied in average amounts from 0.030 to 0.146, and the total deposit of soot for the city was estimated at from one to two million kilograms, or from 1000 to 2000 tons per annum. In winter, owing to meteorological conditions and to domestic fuel consumption, the amount of soot was greater than in summer. Deposits of soot in rain and snow varied from 28 to 62 milligrams per liter. The dust content of the atmosphere was estimated at from 16,000 to 140,000 particles per cubic centimeter.‡ The greatest number was found in the harbor, due no doubt to the outpourings of the vessels which are described as smoking "constantly in a high degree."

No determinations, the results of which are available, seem to have been made in Hamburg with reference to the carbon dioxid content of the atmosphere.

The amounts of sulphuric acid in the atmosphere of Hamburg, as determined by the investigation of 1908–09, are shown in the following table:

SULPHURIC ACID IN THE ATMOSPHERE OF HAMBURG, IN MILLIGRAMS PER CUBIC METER OF AIR

Month	Station A			Station B		
	Max.	Min.	Average	Max.	Min.	Average
June, 1908	0.280	0.123	0.075	.....	.....	.....
July	0.079	0.062	0.048	.....	.....	.....
September	0.285	0.101	0.025	.....	.....	.....
January, 1909	0.512	0.210	0.060	.....	.....	.....
March	0.300	0.179	0.043	0.495	0.257	0.044

In samples of rain and snow the deposit of sulphuric acid amounted to 13.6 milligrams per liter.

In Hamburg, as in London and Manchester, the fogs that prevail are attributed by investigators in part to smoke; but the proximity of the city to the harbor must also be considered. In this connection, the facts presented in the following table are of interest:

AVERAGE NUMBER OF DAYS WITH FOG IN VARIOUS GERMAN CITIES

City	Years	Winter	Spring	Summer	Autumn	Year
Hamburg	1877-85	52.00	22.00	10.00	45.00	130.00
	1887-1906	36.55	16.85	6.30	31.60	91.30
Berlin	1877-85	10.00	1.00	1.00	5.00	18.00
	1887-1906	6.20	2.30	0.70	6.60	15.80
Breslau	1877-1885	28.00	9.00	2.00	28.00	67.00
Kiel	1877-1885	31.00	15.00	8.00	23.00	77.00

In Hamburg and Kiel, which are near the water, the number of foggy days is much larger than in Berlin and Breslau, which are inland. In all these cities the number of foggy days is greatest during the months of the year in which fires are most necessary. The number of foggy days in Hamburg has decreased in recent years notwithstanding an increase in the annual coal consumption. For this decrease some credit has

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* Dr. Kister, "Bericht über die in Hamburg ausgeführten Rauch und Russ Untersuchungen." (Report on Investigations Carried Out in Hamburg on Smoke and Soot.) Gesundheits Ingenieur, Vols. 32 and 33, 1909.

† The term "soot" as employed in this investigation seems to refer largely to carbonaceous materials.

‡ Dr. Gemünd, "Die Beurteilung der Intensität der Rauch- und Russplage unserer Städte mittels des Aitkenschen Staubzählers." (Estimation of the Intensity of the Smoke and Soot Nuisance by Means of the Aitken Dust Counter.) Gesundheits Ingenieur, Vol. 39, No. 2, 1907.

been claimed as being due the smoke abatement activity of Hamburg, which is said to have been vigorous.

The amounts of sunshine in Hamburg, as compared with those in Berlin, during the years 1891 to 1900,[*] are given in the following:

City	Annual Average Total Hours	Monthly Average Hours	Daily Average Hours	Average Per Cent Possible Sunshine	Monthly Average No. Days Without Sunshine
Hamburg...	1,274.8	106.2	3.5	26.8	8.6
Berlin	1,671.5	139.3	4.6	34.4	7.1

The transparency of the atmosphere and the corresponding intensity of daylight were found to vary in Hamburg during the different months of the year, being least during the months of October to March inclusive, when consumption of large amounts of fuel for heating purposes and for domestic use was necessary.

Berlin, Germany

Berlin, with an area of about 24 square miles, has a population of about 2,100,000. Its activities are largely industrial and commercial in character. It has twelve or more railroads, and extensive manufacturing establishments situated on the north, east and south sides of the city. The prevailing winds are from the southwest. Fogs and haze are prevalent. Owing to the comparatively small area of the city, to the location of its factories and to the prevailing direction of its winds, fogs and smoke are driven from the center of the city, and the air is renewed with greater frequency than is the case in Hamburg, London or Manchester.[†] Berlin's annual coal consumption is estimated (1910) to be about 1.5 tons per capita, or a total of about 3,150,000 tons. "Smokeless" fuel in the form of briquettes and peat constitutes about 60 per cent of the fuel consumed. In summer the domestic consumption is about 23 per cent of the whole, in winter about 53 per cent. The annual increase in coal consumption is higher than the increase in population, so that the smoke nuisance has tended to increase. According to Rubner, Berlin air is unmistakably impregnated with smoke, but an analysis of the facts will show that it is less polluted than the air of Hamburg, London or Manchester.

As the conclusion to the reports of his tests conducted to determine the soot in Berlin air, Rubner states: "On the average, in one cubic meter of city air, there is 0.140 milligram of soot with carbon of 60 per cent purity. . . . The minimum is 0.06 milligram of soot and the maximum 0.31 milligram, a ratio of 1 to 5." A comparison of these figures with the corresponding figures for Hamburg shows that the atmosphere of Berlin contains almost as much soot as that of Hamburg.

The results of several series of tests conducted by Rubner to determine the amount of carbon dioxid in the atmosphere of Berlin are set forth in the following:

	PARTS IN 10,000		
	AVERAGE	MINIMUM	MAXIMUM
January, 1906	3.37	3.22	3.46
February, 1906	3.43	3.07	4.02
March, 1906	3.25	3.08	3.47
April, 1906	3.41	3.17	3.66

The amount of carbon monoxid in the atmosphere of Berlin is, Rubner believes, not greater than in the atmosphere of Paris, or about one part in 500,000. Organic carbon consisting largely of hydrocarbons, it is stated, "may be found without doubt in every sample of air, only the quantity is variable."

The amount of sulphurous acid in Berlin air is reported to vary from 1.5 to 2.0 milligrams per cubic meter; the amount of sulphuric acid according to Rubner is 3.28 milligrams per cubic meter. Comparison of the visible and the invisible constituents of the smoke pollution of the atmosphere of Berlin indicates that the content of sulphurous acid exceeds that of soot.

Of nitrites and nitrates, Berlin's air is said to contain from 1.3 to 3.0 milligrams per cubic meter.

Berlin has, besides a diffused smoke nuisance, certain prominent local smoke nuisances, especially in those vicinities in which the factories of the city are located. "The clouding of the horizon on the north of the city occurs even on bright days, in the forenoon and afternoon hours. The haze makes it almost impossible to see the real color of the sky; even low-lying clouds can hardly be clearly distinguished. This haziness sometimes covers half the horizon, the sun is

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[*] Dr. Kister.

[†] Dr. M. Rubner, "Ueber trübe Wintertage, nebst Untersuchungen zur sogenannten Rauchplage der Grossstädte." (Cloudy Winter Days and Investigations in Regard to the So-called Smoke Nuisance of Large Cities.) Archiv für Hygiene, Vols. 57 and 59, 1906.

scarcely visible at all, the cloud masses, the edges of which ought to appear dazzlingly white, look quite brown. When the sun does penetrate, its brightness is greatly diminished. The climatic proof that Berlin is suffering from its own development of smoke and that influences are at work in no small degree on the formation of haze and fog, is certain."

A record of sunshine in Berlin shows that in autumn and winter the city suffers a deficiency in the possible amount of light of from 15 to 16 per cent, and in spring a deficiency of 9 per cent. Records for the years 1891 to 1900, inclusive, indicate that Berlin has 34.3 per cent of possible sunshine, or, on the average, 1371.8 hours annually or 4.6 hours daily. An increase in the amount of sunshine in Berlin has been noted by observers in recent years, a fact which is attributed by Behre* to successful smoke abatement activity in the city.

Dresden, Germany

Several series of investigations which have been made in Dresden by Renk have related to soot but not to the polluting gases in the air nor to the amounts of cloud and sunshine. Dresden has a population of about 500,000. It has in recent years acquired great commercial and industrial importance; its railroads as well as its factories are regarded as factors in smoke production. West and northwest of the city are located industrial districts, but only from the northwest is the smoke carried by the winds over the city in such quantities as to affect the atmosphere. The investigations, however, have definitely established the fact that the greater part of Dresden's smoke is due to domestic fires. The annual coal consumption is estimated at about 2 tons per capita, or approximately 1,000,000 tons. The coal used is mostly lignite, or brown coal, which is not as smoky as the coal used in Hamburg. Dresden has a well enforced smoke ordinance the prohibition of which does not exempt even private residences.

The results of Renk's investigations with reference to soot in Dresden indicate that the proportion of soot in the atmosphere of that city is greater than that in the atmosphere of Berlin or even of Hamburg. The soot content is so great that rain falling on any white object or material distinctly spots it with black. Renk found that the amount of soot was greatest when the air was calm, greater in winter than in summer, and greater in the morning than in the afternoon.

Liefmann makes the statement that the polluting gases in the air of Dresden amount annually to 2,700,000,000 cubic meters.

Other German Cities

While a large number of other German cities are known to be smoky, data regarding the pollution of their atmosphere are meager. Hanover has an annual coal consumption of about one ton per capita and sends into the atmosphere yearly about 1,848,000,000 cubic meters of flue-gases. Most of its smoke is produced by domestic and other small fires. Magdeburg, with an annual coal consumption of about four tons per capita, has less sunshine than Berlin but more than Hamburg. Chemnitz, with an annual coal consumption of 2.5 tons per capita, has a known sootfall greater than that of Berlin. Cologne has an annual coal consumption of four tons per capita, and each year pours into the air 3,700,000,000 cubic meters of flue-gases. One-half of its smoke is attributed to domestic fires. Kōnigsberg, which has a scientific smoke commission, annually burns about one ton of coal per capita. Reports of investigators indicate that the air pollution due to sulphur gases amounts to from 0.01 to 0.5 milligram of sulphur dioxid per cubic meter and from 0.0125 to 0.625 milligram of sulphur trioxid.

Paris, France

Paris has an area of about 30 square miles and a population of about 2,700,000. By reason of its situation on the river Seine and the prevailing direction of its winds, general meteorological conditions render its atmosphere misty during a large part of the year. The sky is clouded about half the year and rain falls on the average during 143 days; there are 40 days of fog and many days of haze. On 226 days of the year the winds blow from the S., S. W., W. or N. W., and on 129 days they blow from the N., N.E., E. or S. E.; there are 10 calm days in the year and 165 days of sunshine.†

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* "Klima von Berlin." (Climate of Berlin.) 1908.

† "Paris," Encyclopædia Britannica, eleventh edition

Observers give values for carbon dioxid found in the atmosphere of Paris, as follows:

	PARTS IN 10,000		
	MEAN	MAXIMUM	MINIMUM
City (winter)	3.19	4.22	2.66
Suburbs	2.70 to 3.29	2.91 to 3.59	2.43 to 2.85

It will be seen that the mean is only slightly above the normal amount of 3 parts in 10,000 for pure atmospheric air. The amount is slightly less than that in Berlin air and much less than that in London air during fogs. In Paris alone among the great cities careful investigations seem to have been made to determine the amount of carbon monoxid in street air. Professor Gautier, special chemist for the Health Department of the city, refers to his investigations as follows:* "According to the result obtained there would be found, on the average, in the streets of Paris 2 volumes of carbon monoxid to 1,000,000 volumes of air, and eliminating one experiment which left me in doubt, this average falls to 0.58; that is, to a little more than half a volume in 1,000,000 of air. We conclude that carbon monoxid is often totally absent from the air of Paris and that it varies between zero and 9 volumes in 1,000,000 of air. There is not an instant's doubt that if my experiments had been made in the quarters and at the hours at which smoke is emitted abundantly, in the neighborhood of the great workhouses, theatres, active factories with electric or motor power, especially while their motors were operating at full force, the maximum figures would have been greatly increased." These investigations seem to be the only ones of their kind. They confirm the common assumption that carbon monoxid, in itself a poisonous gas, if present in the atmosphere of cities, is in amounts too small to be easily detected.

Gautier calculated the total amount of invisible polluting gases in Paris air at more than 20,000 tons per day. He expresses the opinion that this portion of smoke is far more important than the visible portion.

Cleveland, Ohio

In Cleveland the smoke nuisance early became a recognized fact. With the continued growth of the city the nuisance has increased, although constant attempts to check it have been made in vigorous smoke abatement campaigns. With a population of about 500,000 (1910), Cleveland has nearly 4,000 factories. Its coal consumption in 1910 was about 2,800,000 tons.

The average of a series of observations covering the various classes of smoke districts in the city and in a nearby country district, shows the soot content as 14.13 milligrams per cubic meter.

The amount of carbon dioxid found in the atmosphere, as a result of the studies mentioned, is shown in the following: †

CHARACTER OF LOCALITY	PARTS IN 10,000
College campus	3.52
Numerous factories	3.89
Business blocks	4.01
Large factories	3.86
Locomotives and tugs	4.52
Residences	4.31
Numerous factories	4.77
Residences and farms	3.99
Farms outside the city limits (three miles)	3.68

The average of the observations is 4.06 parts in 10,000, which is a higher value than has generally been observed in foreign cities. It will be seen that the largest amount was found in one of the factory districts, although the residence districts registered a carbon dioxid content in the air which is higher than the average. The high degree of pollution in the railroad districts is explained as due largely to the river in the valley of which railroads run. This river is described as being little better than an open sewer.

The average of 13 determinations of sulphur in terms of sulphuric acid showed 33.019 milligrams per cubic meter. The amounts were generally greatest on cloudy days. In the country districts sulphuric acid was either lacking entirely or was present in very small amounts. In the residence districts the content was rather large while in factory districts it was sometimes small. In the railroad and steamboat districts it was large. The deposits of soot on the leaves of trees were found to contain 1.91 to 3.17 per cent of sulphuric acid, and in certain parts of the city very apparent effects of the acid were detected.

Ammonia and other nitrogen compounds seem to have been unusually plentiful in the vicinity of

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* "Les fumées de la ville de Paris." (Smoke of the City of Paris.) Annales d'hygiène, Vol. 45, 1901.

† C. F. Mabery, "An Examination of the Atmosphere of a Large Manufacturing City." Journal of the American Chemical Society, Vol. 17, 1895.

the business blocks, manufactories and the college campus, but not in the residence districts.

The annual number of cloudy days in Cleveland appears to have increased since 1906 and the amount of sunshine to have decreased slightly.

Chicago

In concluding this review of the literature of the atmospheric pollution of cities, it may properly be noted that the studies of the atmospheric pollution of Chicago, the results of which are presented in the several chapters which follow, make up a record which is more complete than any now available for other cities. The facts, as far as they have been apprehended, are presented elsewhere in this report (chapters 104 to 115 inclusive). It will be sufficient in this connection to note that Chicago has a population of 2,185,000 (census of 1910) and an area of 194 square miles. It occupies a level plain and has a lake front of about 23 miles. Of some 300,000 buildings emitting smoke within the city, 40,000 are factories, mercantile houses and storage houses, 100,000 are apartment houses, 130,000 are residences and 30,000 are miscellaneous buildings. There are 39 railroads operating each day about 1,600 different locomotives within the city limits. The record shows that 5,751 steamboats enter its harbors from other lake points during the year and 119 other steamboats operate in city waters.

The annual coal consumption of Chicago is approximately 17,500,000 tons (1912) or about 8 tons per capita. The coal consumed is mostly bituminous. The atmosphere of Chicago is kept in fairly constant motion by breezes, the prevailing direction of which is from the southwest. Its humidity is naturally affected by the proximity of the city to the lake, and fogs of short duration are not infrequent. The average percentage of sunshine for the years 1906 to 1912 was 57.4. During this period the average increased slightly, while the number of cloudy days decreased, a fact which is to be accepted as an indication of progress in smoke abatement. The pollution of the atmosphere is greatest in the "loop" or central business district of the city, notwithstanding the fact that the strictest smoke abatement supervision is maintained in that quarter of the city, and gradually decreases toward the outlying districts. The ammonia pollution, however, follows the opposite rule. The amount of soot and carbon dioxid is greater in the industrial districts than in the railroad districts. The amount of carbon dioxid in residence districts also exceeds that in the railroad districts. But the differences between the railroad, the industrial and the residence districts are, after all, not significant. On the whole, while the coal consumption per capita is far greater than that of any other city covered by this review, the air pollution in Chicago appears to be less, relatively, than in most other cities; certainly less than in those cities with which it should normally be compared. The facts sustaining this statement are set forth in the chapters which follow.

101.13 Conclusions to be Drawn from the Literature Relating to Smoke and the Atmosphere of Cities: Among the facts which are made clear by the preceding review, the following may be noted as those of most importance:

1. The extent to which the atmosphere of cities is polluted is conveniently and quite commonly judged by comparing it with the normal air of the open country as a standard. The characteristics of normal atmospheric air being known, all that is necessary is to point out the differences between such characteristics and those of city air.

2. In the study of the atmosphere of cities, methods have been devised which, while in part successful, are still largely experimental. The methods commonly employed in determining the solid content of smoke polluted air are admittedly less satisfactory than those used in determining the gaseous content. It is coming to be emphasized more and more that effective smoke inspection involves technical knowledge and skilled use of laboratory equipment. A comparative study of the air of cities based on such methods is being generally urged.

3. The comparison of the air of cities with that of the country has revealed characteristics which may, and apparently must, be attributed to the smoke of the cities; but it is also true that they may in part be attributed to other sources, as, for example, leakages from gas mains, the pollution due to sewers, the dust of the streets and decaying organisms. Air analysts have, admittedly, not been able to separate clearly and absolutely the products of combustion as dispersed in the air from those of other agents of air pollution.

4. The industrial activity of all important cities has brought about an increase in coal consumption which is greater than the increase in population. Smoke formation and the consequent pollution of the atmosphere by smoke have in recent years tended to increase and have

done so, except so far as the adoption of various measures in smoke prevention have proved effective. But the effects of atmospheric pollution by smoke are as yet quite uncertain. Scientific studies of the atmosphere of cities are of recent origin and the time which has elapsed since the initial work in this direction has been too short for the attainment of accurate results of permanent value. No one individual and no one city can accomplish the work that should be done. The observations must be numerous and should extend over decades. Certain inconsistencies in the use of terms must be eliminated. It is only by such means that conjectures can be made to give way to facts and anticipations to scientific inferences.

5. Although soot and its effects have formed the principal subjects of complaint, less is really known of them than of the gases of smoke.

6. The fact appears firmly established that there is a well-defined relation between smoke and fog and that the presence of smoke induces fog.

7. It seems to be agreed that while smoke is not the only factor affecting sunshine, it is a function of the amount of sunshine. Increased quantities of smoke diminish the number of hours of sunshine.

8. The amount of carbon dioxid in the atmosphere of cities is, as a rule, only about 0.01 per cent greater than that in country air. The sulphur compounds in city air usually constitute a more important element than is the case in country air. Sulphur compounds are generally thought to be due to the combustion of coal.

9. The amount of pollution in the atmosphere at any given time or place depends very much upon climatic conditions. On calm days, smoke is much more in evidence than on windy days. Certain large cities possess a great advantage in prevailing winds that carry off much of the polluted air. Other things being equal, a dry atmosphere is more polluted than an atmosphere which has been washed by recent rain or snow, but a permanently humid atmosphere serves to intensify the pollution caused by smoke. In a number of cities a haze more or less permanent and independent of meteorological conditions has been observed and has been attributed to air pollution due to products of combustion. This has been noted particularly in Manchester, London, Paris and Berlin.

10. Among the sources of the pollution of city air by smoke, the world over, domestic chimneys are very conspicuous. The mention of them by observers and students is much more frequent than the mention of such other sources as railroads and steamboats.

11. A comparison of the facts available with reference to Chicago and those relating to other cities presents some features of particular interest in the present study. It is made apparent that the extent of the air pollution due to smoke in Chicago, as revealed by the studies reviewed, is not more serious than that in other cities. In many respects, in fact, conditions in Chicago are much better than those in other cities; the per cent of possible sunshine is higher than that of Cleveland and of all the European cities studied, and reports show that the content of sulphur compounds in the atmosphere is lower in Chicago than in other cities. The high average wind velocities in Chicago serve materially to dissipate smoke and to decrease its polluting effects.

METHODS AND REGULATIONS EMPLOYED IN SMOKE ABATEMENT

101.14 Means in Smoke Abatement: The abatement of smoke has been a subject of public interest in domestic and foreign cities for many years. Various methods have been employed at different periods with varying degrees of success. At present the methods most generally in use are:

1. The enactment and enforcement of smoke abatement ordinances.
2. The enlightenment of the public with regard to both the necessity of abating smoke and the direct means by which this may be accomplished.

In most countries, results in smoke abatement have been dependent upon legislation. Generally, the enforcement of laws has been accompanied by educational processes. An exception to this, however, is found in Germany where smoke abatement ordinances are rare and activities in smoke abatement are largely directed by organized private effort.

In many instances, laws for the prevention of smoke have been drawn so loosely that it has been impossible to maintain their validity before the courts. In other instances legislation has been enacted without proper consideration of the difficulties of the problem, with the result that its provisions could not long be enforced. It is obvious that the beneficial effects to be expected from legislation will depend primarily upon the extent to which the legislative act recognizes the real nature of the pollution arising from smoke, the means to be employed in detecting its presence and the limitations imposed by present-day methods upon those who desire to be obedient to the requirements of the law.

101.15 Classification of Smoke Producers: Smoke abatement ordinances have generally recognized some classification of smoke producers. Such classifications have been based upon the amount of smoke produced, upon the kind of furnace or fireplace involved, whether stationary or movable, upon the nature of the work performed by the furnace, or upon the practicability of smoke prevention. In a few cases, classifications have been made upon the basis of convenience in inspection or that of the size and number of the plants.

The British Commission of 1846 concluded that private fires should be considered separately from those of "steam engines, breweries and other works generally," and that the latter class should be subdivided so as to distinguish between furnaces from which a discharge of smoke might be prevented without damage to the industry, and those with regard to which the opposite might be true. Movable plants were not taken into consideration at all by this Commission but were included a few years later in the London ordinances. A proper classification of smoke sources is being recognized as necessary in the work of smoke abatement.

The most elaborate classifications based upon the nature of furnaces seem to be those of Sheffield, England, and St. Louis, Mo. The Sheffield classification is as follows:

1. Boiler plants.
2. Metallurgical furnaces.
3. Kilns and coke ovens.
4. Private dwellings.

This classification recognizes the peculiar conditions existing in Sheffield as a steel manufacturing center. Special claims are set forth by the steel mills to the effect that the uneven demands which the manufacture of steel makes upon furnaces cause unusual difficulty in smoke prevention.

The present classification in St. Louis is as follows:

1. High pressure boiler plants.
2. Low pressure or heating plants.
3. Locomotives.
4. Brick and fire clay kilns.
5. Residences, bakeries, steam rollers, etc.

In London and in Leeds, England, although the conditions are equally complicated, the classifications are less elaborate. The London classification is as follows:

1. Steam boiler furnaces. Other furnaces used in any manufacturing or trade process.
2. Private fires.
3. Furnaces of steamboats.

The classification in Leeds is as follows:

1. Ordinary steam boiler plants.
2. Domestic fires.
3. Furnaces used in processes of dyeing, refining, puddling, smelting, or in making bricks, tiles, etc., to which special conditions are attached.

The classification in Paris, France, has special features which are doubtless due to the preponderance of small industries. Establishments are divided into "classed" and "unclassed." The former division includes the following:

1. Establishments concerned with the generation of electric currents.
2. Steam boiler plants.
3. Plants containing machinery moving at high velocities.

The "unclassed" industries have included at different periods from 10 to 18 special industries, such as power plants, petroleum refineries, gunpowder factories and manufactories of aluminum, celluloid, felt hats and other articles.

The classification adopted in Boston, Mass., disregards the nature of the industry concerned and takes account only of the size and character of the furnace. It was devised with special reference to a discriminating and equitable estimation of the smoke discharged. It is as follows:

1. Stationary stacks having an inside area at top not exceeding that of a circle 5 feet in diameter.
2. Stationary stacks, not above included, having an inside area at top not greater than that of a circle 10 feet in diameter.
3. Stationary stacks of still greater area at top.
4. Stacks of vessels having an inside area not exceeding that of a circle 4 feet in diameter.
5. Stacks of vessels having an inside area greater than that of a circle 4 feet in diameter.
6. Stacks of steam locomotives.

The Committee of Investigation of the Mellon Institute of Industrial Research and School of Specific Industries of the University of Pittsburgh has adopted a mixed classification which is presented in the following:

1. Business section of the city.
2. Manufacturing plants.
3. Railroads.
4. River steamboats.
5. Residences.
6. Miscellaneous plants, such as contractors' hoisting engines, steam rollers, etc.

A similar mixed classification is in use in Chicago and may be given here for the sake of comparison, although the practice of Chicago is considered in full elsewhere in this report (chapter 104):

1. Central district of the city (including hotels, department stores, business blocks, office buildings, club buildings, public buildings, etc.).
2. Miscellaneous power plants.
3. Flat buildings.
4. Domestic heating.
5. Special furnaces (heating and melting furnaces in steel plants, terra-cotta plants, malleable iron plants, forge shops, enameling plants, annealing ovens, baking ovens, china kilns, etc.).
6. Railroad locomotives.
7. Boats.

It will be seen that most of these classifications have reference chiefly to boiler plants, special furnaces and residences. In many cities little effort has been made to effect an abatement of smoke from residences and special furnaces, while boiler furnaces have received a much greater share of attention. It is known, however, that domestic fires are of the greatest importance as smoke producers. In London, Glasgow and Manchester domestic smoke is estimated at from 44 to 80 per cent of the whole; in Dresden, Hanover, Cologne and other German cities it comprises from 40 to 50 per cent; in Paris it is estimated at 80 per cent. No close estimates have been made for American cities, but in Cincinnati, Indianapolis and Louisville domestic smoke has been recognized as a very considerable portion of the whole. It is well known that the amount of smoke produced by domestic fires, as compared with that produced by industrial furnaces, is greatly out of proportion to the amount of coal consumed, owing in part to the poor quality of fuel used in many apartment buildings, and in part to the careless methods generally employed in burning it. The relative importance of domestic fires as smoke producers in Chicago has in recent years been favorably affected by the increased use of gas for cooking. However, the large quantities of smoke produced from a single source in industrial establishments, the rapid industrial development of modern cities, and the difficulties of inspecting the enormous number of domestic fires, have all operated to focus the attention of law makers and the efforts of those entrusted with the enforcement of smoke abatement ordinances upon industrial furnaces rather than upon domestic fires.

Mr. G. Beilby,* in an address before the Society of Chemical Industry, presented an estimate of the amount of coal consumed by various industries in Great Britain during the year 1898 as an index to the relative smoke production by these services. The values given cannot be accepted as a direct measure of the amount of smoke produced because certain industries utilize waste products to an extent which practically eliminates visible smoke, and also because, in the operation of domestic furnaces, the firing is so unscientific as to make them responsible for a correspondingly large proportion of smoke. In a measure, however, they serve to suggest the relative importance of the several services. Mr. Beilby's estimate is as follows:

AN ESTIMATE OF THE AMOUNT OF COAL CONSUMED BY VARIOUS INDUSTRIES IN GREAT BRITAIN IN 1898

Service	Tons	Per Cent of Total
For the Production of Power		
Railroads	10,000,000 to 12,000,000	....
Coasting steamers	6,000,000 to 8,000,000	....
Mines	10,000,000 to 11,000,000	....
Factories	38,000,000 to 40,000,000	....
Total for the production of power	76,000,000	48.4
For the Production of Heat for Industrial Purposes		
Blast furnaces	16,000,000 to 18,000,000	....
Steel and iron works	10,000,000 to 12,000,000	....
Other metallurgical works	1,000,000 to 2,000,000	....
Chemical works—potteries and glass works	4,000,000 to 6,000,000	....
Gas works	13,000,000 to 14,000,000	....
Total for the production of heat for industrial purposes	46,000,000	29.4
Domestic fires	35,000,000	22.2
Totals for all services	157,000,000	100.0

The report of the Chicago Department of Smoke Inspection for the year 1910 presents an estimate of the city's fuel consumption, as follows:

AN ESTIMATE OF THE AMOUNT OF COAL CONSUMED BY VARIOUS INDUSTRIES IN CHICAGO IN 1910

Class	Service	Tons	Per Cent
1	Central district of city	1,500,000	15.0
2	Miscellaneous power plants	4,500,000	45.0
3	Flats	750,000	7.5
4	Domestic fires	650,000	6.5
5	Special furnaces	600,000	6.0
6	Railroads	1,850,000	18.5
7	Boats	150,000	1.5
	Totals	10,000,000	100.0

The small percentage of coal (14 per cent) used for domestic purposes as compared with England (22.2 per cent) is probably due, in some measure, to Chicago's extensive use of gas for cooking. The results of the Committee's investigations with reference to the fuel consumed by different services are elsewhere presented (chapter 104).

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*Presidential Address, Journal of the Society of Chemical Industry, Vol. 18, 1899.

101.16 Supervision of the Performance of Furnaces: If the regulation of smoke is to be regarded primarily as a factor in promoting the welfare of the community and not solely as a police measure, it is clear that provision must be made not only for enforcing the regulations, but also for giving instructions with reference to the proper construction and management of furnaces. In this connection it is interesting to note that practically all the advances made in Germany toward the elimination of the smoke evil have been along these lines. In England and in the United States, smoke inspectors are often charged only with police duties and are not expected to give assistance or instruction. In a number of municipalities there are no special smoke inspectors, the enforcement of the ordinances being delegated either to the police or to the health department. In a few cities of the United States there are, besides the city smoke inspectors, inspectors appointed and paid by the railroads, who co-operate with the city inspectors and report to them at stated intervals. Thus, in New York City each railroad has several men charged with the duty of supervising the performance of locomotives in such manner as to abate smoke. In Boston each railroad has one man constantly making observations and reporting careless or unnecessary smoke emissions. In Philadelphia, Rochester, Milwaukee, Minneapolis, St. Louis, Toledo, Detroit, Cleveland, Cincinnati, Pittsburgh and Chicago, smoke inspectors are or have been employed by the railroads.* In cities where no special smoke inspectors are provided by the railroads, locomotive engineers and firemen are instructed to observe the requirements of the city ordinances as to smoke abatement.

The qualifications of smoke inspectors in the United States respond to a high standard. The smoke ordinances of more than half the cities in the United States and Canada specify that the chief smoke inspector shall be a trained engineer. In some of the cities the deputy inspectors must possess the same qualifications as the chief inspector. In general, it may be said that the smoke inspectors are amply qualified to supervise the performance of furnaces and to co-operate intelligently with engineers and firemen in abating smoke. In foreign countries the ordinances are less explicit on this point, but it is known that there are mechanical experts acting as smoke inspectors in such cities as Sheffield, Manchester, Liverpool, Glasgow and London. The chief inspectors of the stoking societies of Germany are also experts. It is being generally recognized that smoke inspection is a technical art which requires special knowledge and skill. It is also understood that certain qualities of character such as good judgment, tact and moral incorruptibility are necessary. The function of smoke inspection has ceased to be merely that of exercising a strict surveillance with a view to detecting violations of the law, and is now recognized as including friendly and intelligent co-operation between smoke inspectors and plant owners. Instruction and advice are freely interchanged.

"The personnel of the department is of great importance, as the suppression of smoke is in reality an engineering problem of no small magnitude. The work of collecting data, ordering changes, supervising new work and giving instructions, requires a man of technical training. He should be competent to conduct tests and to make analyses, be of wide practical experience, diplomatic to a degree, and of unimpeachable integrity. His title should be that of engineer and his position must be one of dignity. Such a man can command an ample salary and a corresponding one should be attached to his municipal position. Under him should be a fireman familiar with the care and operation of the various smoke preventing devices in use."†

In a few cities where less attention is given to the punishment of violators of the smoke abatement ordinance than to instruction in the proper management of furnaces, the method ordinarily pursued is described by one writer as follows: "When it is observed that a stack is emitting an undue amount of smoke, the inspector immediately calls on the offending party to ascertain the conditions under which the law is being violated and the cause of the smoke. If the trouble is found to be due to some disarrangement or mishap, a reasonable time is allowed for repairs. If it is found that repairs are not needed, the

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*The railroads of Chicago are at this date (September, 1914), employing 38 men who devote all their time to smoke inspection in connection with locomotive service and 12 others who devote the larger part of their time to such work.

†R. P. King, "Municipal Control of Smoke." Engineering News, Vol. 54, 1905.

inspector studies the conditions and advises the parties how to avoid the continuance of the difficulties; then, if there is no improvement, legal proceedings are taken and the desired result is obtained. As to the means of getting smoke preventing devices into use, the inspector informs owners or occupants of buildings, after carefully studying conditions in the plants, as to the particular appliance best suited to their needs, and suggests a conference with users to enable them to form their own opinion." This seems to represent fairly well the educational plan of smoke inspection.

101.17 Enforcement of the Ordinances: The legal procedure in connection with violations of the smoke ordinances has usually been about as follows: When a violation has been noted, warnings have been sent to the offender. If no attention has been paid to the warnings, summonses have been issued and the case has been taken into court for the purpose of assessing fines. An objection to the issuance of notices has been found in the fact that offenders often claim exemption on the ground of not having received the notification. Reports from British towns in 1910 show that, compared with the number of warnings issued, the number of summonses was small and the number of fines still smaller. In many cases the amount of the fine was small, the average being less than two pounds ($10.00). In America, even when smoke inspectors have done their utmost to secure a conviction, the courts have often practically nullified their efforts by assessing very small fines or by remitting them altogether. In a few American cities, however, fines have of late years been used effectively in securing results regarded as impossible by other means. In Germany the opposition to legal procedure is outspoken. In Paris, France, the number of legal processes amounted to 144 in 11 years or an average of about 13 a year.

The work of a well organized smoke department in one of the cities of the Middle West is shown in the following record:*

Number of smoke charts made		82
Number of photographs taken		400
Number of written warnings		96
Number of letters written		236
Number of letters received		245
Number of complaints received		59
Number of cases dismissed		0
Number of sentences suspended on payment of costs		14
Number of cases in court fined $25 and costs		41
Number of cases in court fined $50 and costs		5
Number of cases in court, 2d offense, 1912		6
Number of cases in court, 3d offense, 1912		2
Total number of cases in court		60
Total amount of fines imposed		$1,275.00
Total cases in protected zone outside city		14
Observations made on chimneys and stacks		1,452
Total installations		54
Jones underfeed stokers	12	
Murphy stokers	2	
Chain or traveling grate	10	
Swift stokers	4	
Erie stokers	4	
Hawley down-draft	2	
Miscellaneous (arches, jets, etc.)	20	
Chimneys and stacks rebuilt		8
Total paid in salaries (smoke inspector, two deputies and one clerk photographer)		$5,243.70

101.18 The Enlightenment of the Public: It has been generally recognized that success in smoke abatement is dependent upon proper enlightenment of the public both in order to secure the enactment of reasonable and effective laws and to obtain the public's endorsement and support of a reasonable interpretation and enforcement of such laws. This process seems now to be going on with encouraging rapidity. Many agencies are contributing to it. Select committees or commissions of experts in law, medicine, chemistry and mechanics have given it their attention. Men of affairs have taken part in movements designed to further develop the problem. Frequent conferences have been held and their proceedings printed. Many investigators and students have lectured and written on the subject, and numerous popular books and articles have been devoted to it.

The necessity for specific instruction of owners and managers of plants has also been recognized. It has been shown that constructive co-operation and intelligent instruction, both as to the inconvenience and injury a community suffers from smoke and as to the means by which smoke may be prevented, yield gratifying results. Important agencies devoting attention to technical instruction include organized societies, lectureships and special schools. These exist in many cities, especially in those of Germany. The object of these agencies is not merely to collect and disseminate correct information relating to all phases of the smoke question, but more specifically to give instruction to managers of plants as well as to engineers and firemen with regard to the various means which have been found effective in

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*Annual Report of the Smoke Inspector, City of Milwaukee, Wis., for the year 1912.

reducing smoke. A special periodical devoted to dust and smoke (*Rauch und Staub*) has been published in Germany since 1910.

British commissions instituted investigations and submitted valuable recommendations in reports published in 1843, 1845, 1846 and 1855 respectively. In 1881, 1882, 1895, 1902, 1904, 1905, 1911 and 1912 British committees conducted series of tests and held exhibitions and conferences the proceedings of which were made public. From 1894 to 1897 and from 1901 to 1905 commissions were at work in Paris, and the reports of the Department of Public Inspection show that the findings of these commissions have been constantly appealed to as important aids in municipal smoke prevention. The United States Government has tested fuels and furnaces at St. Louis, at Pittsburgh and at Norfolk with special reference to the smokeless combustion of coal, and has published numerous bulletins setting forth the results of its work.* At the University of Illinois fuel tests have been made. The Pennsylvania Railroad, in 1904 at the Louisiana Purchase Exposition at St. Louis, made an extended series of locomotive tests which were of unusual value in establishing fundamental facts with reference to combustion in locomotive service. Similar tests have been made at Purdue University and elsewhere.

In London, Leeds, Manchester, Glasgow, Hamburg, Königsberg, Dresden, Berlin, Paris, Cleveland, Chicago and other cities, technical experts have investigated and reported upon atmospheric pollution and its effects. In many German cities, schools of stoking have long existed, and in others practical stoking societies directed by experts have been doing efficient work. The Hamburg society, founded in 1902, is perhaps the most important of these organizations.

Of the numerous general societies for the study of smoke abatement, the London Coal Smoke Abatement Society, which has been at work since 1898, is prominent. There are also important societies of similar character in Leeds, Sheffield, Glasgow and Manchester. The Smoke Abatement League of Great Britain, established within the past decade, gives promise of accomplishing important results.

In America there have been conferences such as that held at the Franklin Institute, Philadelphia, in 1897, a full report of which was published in the Journal of the Institute. Of special importance at the present time are the extensive investigations undertaken by the Mellon Institute of the University of Pittsburgh aided by some thirty or more experts, including architects, bacteriologists, botanists, chemists, engineers, meteorologists, physicians, physicists and psychologists.

It is evident from a survey of the preceding paragraphs that a vast amount of attention is being devoted to the subject of smoke abatement, and that efforts are being made to keep the public well informed with regard to it.

101.19 Fuels: The abatement of visible smoke may be brought about either by the selection of smokeless fuels or by the use, under properly controlled conditions, of fuels which normally produce a considerable amount of smoke. The choice of fuels is, of course, dependent upon natural conditions. It must be borne in mind, however, that the terms "smoky" and "smokeless" as applied to fuels are commonly used with reference only to the visible constituents of smoke. If the invisible constituents are also considered, there are no solid fuels that are entirely smokeless, for there are no solid fuels of which the products of combustion are entirely free from dust or soot.

The fuels commonly called smokeless include anthracite, coke and the various forms of gaseous fuels. The principal smoky fuels are bituminous coals and lignites.

Statistics relating to fuel production in the United States, Great Britain and Germany show that the total production in 1912 of the principal fuels was as follows:†

FUEL PRODUCTION IN 1912

Kind	United States	Great Britain	Germany
Total coal production (tons)	534,466,580	291,666,299	285,974,649
Bituminous (tons)	450,104,982	....	....
Anthracite (tons)	84,361,598	....	....
Petroleum (bbls., 42 gals.).	222,113,218	....	995,764
Coal briquettes (tons) ...	220,064	....	....
Coke (tons)	43,983,599	....	....

Bituminous coal is found very widely distributed throughout the world. Its abundance makes it of first importance, notwithstanding its large content of volatile, smoke producing materials. The variation in the composition of

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*Reports of the United States Geological Survey and of the Bureau of Mines.

†Government Report on the Mineral Resources of the United States for 1912.

Illinois bituminous coal as shown by an extended series of analyses[*] is as follows:

	PER CENT
Fixed carbon	26.3 to 66.5
Volatile matter	24.5 " 57.1
Moisture	1.4 " 14.5
Sulphur	0.0 " 4.4
Ash	2.7 " 35.0

Lignite and brown coal are very similar to bituminous coal. On the continent of Europe, especially in central Germany, they constitute the most important fuel supply; in the United States they are abundant in certain regions, particularly in the Northwest, but they have not yet come into extensive use. In the future they will probably become important local sources of supply. Reports from the German cities of Halle and Quedlinburg, in which lignite and brown coal are chiefly used, indicate that they burn without excessive carbonaceous smoke but produce a dust nuisance as annoying as the smoke nuisance. In Dresden, where lignite is burned, soot is troublesome.

Anthracite is found in only a few parts of the world and in comparatively limited areas. This fact, together with the great demand for it as a "smokeless" fuel, has established a price which prohibits its use in many parts of the world. Aside from this, however, it is not satisfactory as a fuel in cases in which great and sudden increases in the amount of heat to be supplied are necessary. Its use is therefore confined mainly to furnaces in which an equable and continuous heat is desired. "Coal containing much gas is, in general, of incomparably greater value in the industries than coal containing little gas."[†]

Coke is not well suited to the furnaces of steam boilers. Like anthracite, it is lacking in combustible gases and is incapable of responding to rapid changes in the demand for heat. Its use under boilers is increasing, however, in various cities of the United States, and also in England and in Germany.

Other natural and prepared fuels including coalite, briquettes, powdered coal, oils, natural gas and manufactured gases have been used locally or for special purposes in many parts of the world. Most of these special fuels may be burned with a minimum production of visible smoke. The use of such fuels is limited, however, by the supply or by the present cost of production, and until these conditions may change they cannot be relied upon as important factors in smoke abatement.

101.20 Conclusions with Reference to Methods and Regulations Employed to Abate Smoke: The preceding review of the methods and regulations employed to secure an abatement of smoke reflects a world movement and presents many facts, among which the following are noteworthy:

1. A common defect in smoke abatement ordinances has appeared in the fact that they have not been based upon a full understanding of the difficulties of the problem they have sought to solve, and where this has been the case the ordinance has proved an insufficient instrument.
2. It has been shown conclusively that legal prohibition against smoke production does not in itself serve to secure satisfactory results. When prohibition has been accompanied by a campaign for intelligent furnace construction, by measures designed to educate owners, engineers and firemen, and by effective inspection, it has proved an instrumentality of high value.
3. Even where legal prohibition is lacking, experience indicates that noteworthy progress may be made as a result of movements for the education and enlightenment of all who are in any way concerned with the utilization of fuel.

PHYSICAL, MECHANICAL AND CHEMICAL MEANS OF ABATING SMOKE

101.21 General Means Employed: Progress in smoke abatement throughout the world, as revealed by a study of the literature, has marked the application of many different methods to the solution of the problem. A review of the discussions and an account of the more important work accomplished, follows.

101.22 The Removal of Sources of Smoke from Cities: The removal of all smoke producers to points outside the limits of cities was one of the earliest means of smoke abatement proposed, and though it appears particularly drastic, it is still sometimes advocated. Naturally, such a proposal always arouses opposition and has seldom, if ever, been literally adopted. In Paris, Berlin and other foreign cities, the

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[*] Kent, "Steam Boiler Economy," p. 73, New York, 1908.

[†] F. Haier, "Die Beziehungen zwischen der Rauchentwicklung und der Ausnutzung der Brennstoffe, und die Mittel und Wege zur Rauchverminderung im Feuerungsbetrieb." (The Relation between the Development of Smoke and the Utilization of Fuel, and Ways and Means of Abating Smoke in the Working of Furnaces.) Zeitschrift des Vereines Deutscher Ingenieure, Vol. 49 1905.

bakeries and other small industries have been responsible for creating a smoke nuisance which has aroused a marked public sentiment demanding their removal, at least from residential districts. In a report of the city smoke inspector of St. Louis, it is recommended that brick kilns and other objectionable smoke producing industries be located, in the future, outside the city limits. In the District of Columbia, the establishment of railroad freight yards outside the limits of the city of Washington has been demanded and secured.

Obviously, such measures are in the nature of makeshifts; they do not attack the fundamental problem of smoke abatement. The mere removal of certain smoke producers to points outside the city limits is not in itself sufficient to give the relief desired. Unless the distance to which they are moved is considerable the effect produced is slight. Only at times when the direction of the wind may be such as to place the sources of smoke to the leeward of the city, does the element of removal really become effective. The complete removal of smoke producing industries from cities has not often been advocated.

101.23 Smoke Drains: The employment of smoke drains or sewers was one of the early remedies proposed for the smoke nuisance and this remedy has also been suggested in recent years. The plan contemplates the use of large and tall chimneys, centrally located, to which smoke drains leading from adjacent fuel consuming plants may be connected. It has been stated that such an arrangement, if properly designed, would result in the discharge of smoke into the atmosphere at such height that it would be carried beyond the limits of the thickly populated districts before being finally condensed and deposited. The records do not indicate that such a system has anywhere been put into extensive operation. Its possible results are largely speculative.

101.24 Central Heating and Power Plants: The abatement of smoke by means of central heating and power plants involves a practice which is well understood in the United States, where "there is, at present, a general tendency to centralize power, heating and gas plants. . . . There are now more than 150 central heating plants in the United States furnishing steam and hot water to residences or business buildings or both. The greater number are located in coal producing states. They can be operated without smoke under favorable conditions." * According to many writers the amount of coal consumed by central plants with practically no visible smoke would, if burned in domestic fireplaces or in furnaces of small industries, give rise to large volumes of such smoke. It has been suggested also that central plants may be located at some distance from residential districts or even entirely outside of cities.

101.25 Smoke Washing Devices: Smoke washing was early suggested as a means in smoke abatement.† An experiment in smoke washing, considered of sufficient importance to be brought to the attention of one of the sections of the British Association for the Advancement of Science, has been in progress for a number of years in connection with industrial plants at York, England. The adoption of the washer was a result of the fact that the only fuel available at reasonable cost was a very dusty one, whereas the proprietors of the establishments concerned (cocoa works) were especially desirous of having model factories entirely free from dust and smoke. "The first section of the smoke washer (a chamber 37 feet long, 14 feet, 6 inches, wide, 17 feet high) constitutes a resting and saturating chamber in which the velocity of the gas is greatly diminished and in which a large amount of water vapor is taken up. Here most of the heavy grit is deposited. The gas is then chilled and washed in succeeding sections, causing the deposition of the lighter fumes and smoke. This deposition is greatly assisted by the condensation of part of the water vapor taken up in the first section. . . . A comparative set of experiments upon the washed and unwashed gases showed that the whole of the grit and dust and practically the whole of the solids in smoke and the sulphur acids are removed in the washer. The amount of grit collected was about 1600 pounds per 24 hours or, considered as dry material, was equivalent to 1.5 per cent of the fuel burned. . . . Similar smoke washers might be adopted with great benefit to the neighborhood by many large factories and generating stations and could be run at a moderate

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*D. T. Randall, "The Smoke Problem at Boiler Plants—A Preliminary Report." United States Bureau of Mines, Bulletin 39, 1912.

†See some of the early numbers of the Mechanics' Magazine, three-quarters of a century ago.

expenditure wherever a cheap and plentiful supply of water is available."[*]

In May, 1909, the Chicago & North Western Railway installed in one of its roundhouses in Chicago apparatus for producing mechanical draft to exhaust the smoke from the smoke-jacks into a large conduit, thence through an exhaust fan into a large washing chamber in which the volume of smoke passed through sprays and sheets of water. In this manner, the greater portions of the carbonaceous materials and dust were precipitated, and the cleansed gaseous products of combustion were allowed to escape into the atmosphere. The emissions, after passing through the washing chamber, presented a light gray appearance somewhat resembling that of steam. The device proved very satisfactory except for the fact that the iron work used in its construction soon became affected by the corrosive action of the sulphuric acid in the stream of gases. Devices of similar design, but constructed of concrete, transite asbestos board and other materials not subject to the action of corrosive gases or acids, have since been installed.[†]

A notable recent installation is that of the Lake Shore & Michigan Southern Railway at the Englewood Terminal of that road in Chicago. The smoke collecting and washing system of the plant is reported[‡] to be so far perfected that its operation enables the road fully to meet the requirements of the smoke abatement ordinance of the city. The smoke is made to pass under an inclined apron, the lower edge of which approaches the surface of the water. A film of water also runs down over the apron and passes in a shower from its lower edge to the water receptacle below. The products of combustion, striking the inclined apron, are deflected downward toward the surface of the water and, in passing under the edge of the apron, they pass through a descending shower of water. Many of the larger particles are projected into the water before the shower is reached and those that remain are carried downward by the shower. A jet of steam is introduced just before the smoke comes in contact with the water. The resistance offered the products of combustion in passing under the apron and through the shower tends to impede their movement, and the cooling effects to which they are exposed tend to suppress the draft action arising from the chimney. Losses thus sustained are made good by the introduction of a fan. Another smoke washing device, known as a "cinder catcher," operated by the New York Edison Company in New York, is said to remove 95 per cent of the solid matter from the stack gases.[¶]

These descriptions will serve to indicate the state of the art of smoke washing as set forth in technical literature. The possibilities of the process have long been understood; its application has been retarded by difficulties encountered in maintaining the plant in the presence of the corrosive acids developed by the process, and by operating costs arising from the consumption of water and power (see chapter 115).

101.26 Electric Condensation and Deposition of Smoke Particles: The condensation and deposition of the particles of smoke by means of electricity was suggested as early as 1886, by Prof. Oliver Lodge of the University of Birmingham, England. Recently the suggestion has been put into practice as a means of collecting dust discharged from the stacks of smelters and cement works. In special instances where the ordinary methods of smoke prevention are found particularly difficult of application, "electrical precipitation may eventually be found of use, for experiments show that it acts upon ordinary smoke in essentially the same manner as upon the fumes and dust of smelters and cement works."[§] The New York Edison Company has experimented with the process as a means for the suppression of fuel dust and ash from the stack of one of its stations. The process involves the passing of the smoke through a metal grating, or a series of such gratings, which are energized electrically. Approaching soot or dust particles, responding to electrical influences thus set up, attach themselves to the grating as do metallic particles to a magnet. The grating is cleaned by interrupting the current (see chapter 115).

[*] J. B. C. Kershaw, "Washing Dust and Smoke from Chimney Gases at York, England." Engineering News, Vol. 65, No. 9, p. 255. 1911.

[†] Report of the Department of Smoke Inspection, City of Chicago, February, 1912.

[‡] Railway Review, Chicago, Feb. 14, 1914.

[¶] For a description of this device, see section 115.05.

[§] F. G. Cottrell, "The Electrical Precipitation of Suspended Particles." Journal of Industrial and Engineering Chemistry, Vol. 3, No. 8, 1911. See also a paper entitled, "The Theoretical and Experimental Consideration of Electrical Precipitation," by A. F. Nesbit, and a paper entitled, "Practical Application of Electrical Precipitation and Progress of the Research Corporation," by Linn Bradley, both presented at the third Midwinter Convention of the American Institute of Electrical Engineers, New York, February 19, 1915.

101.27 Increased Use of Gas and Electricity: The literature reviewed shows that the use of appliances for burning gas and for utilizing electricity for heating, cooking and power purposes as a substitute for solid fuels has of late years increased. The following figures show the extensive use of gas stoves in London:

	NUMBER OF CONSUMERS	NUMBER OF COOKING STOVES	PER CENT
Ordinary	385,578	192,915	50
Slot-meter	448,690	354,493	79
Totals	834,268	547,408	65

"Within the last ten or twelve years, by the introduction of the penny-in-the-slot meter, almost all of the wage-earning citizens of London have been supplied with gas, whereas previously not one in a hundred used gas. . . . The demand for gas cookers is still maintained, the three companies supplying not less than 700 to 800 a week."[*] This means presumably the elimination of a corresponding number of smoky coal fires. In 1910 the number of gas stoves and other heating and cooking appliances supplied by the principal London gas companies exceeded 1,300,000. In Glasgow the use of gas appliances is directly encouraged by the City Corporation, which, between March and September, 1912, loaned free to consumers as many as 36,000 cookers. In 1910, 30 or more of 55 British towns that reported, rented gas cookers to consumers.

In Chicago the use of gas as a substitute for solid fuels has increased rapidly in recent years. Gas is chiefly used for domestic cooking. The number of gas stoves in use is estimated to be in the neighborhood of 400,000. Gas is extensively used also in bakeries and in various incidental services.

The use of gas in power plants has become extensive. The number of plants operated by producer gas during the last decade has increased materially. In England, the number of producer gas plants has become so large as to cause an advance in the price of anthracite, from which the greater portion of the producer gas in England is generated.[†] In Germany, engines to run on producer gas are built for many different purposes.

Many writers show that, for a number of purposes, electricity serves as a smoke preventive. In England, it is stated, electric power is utilized in most of the textile factories. In printing works it is especially valuable, and it is fast becoming indispensable in great engineering workshops.[‡] In flour mills, bakeries, saw mills, woodworking shops, laundries, cement works, paint mills, butter factories, breweries, paper mills and foundries, electricity is also said to be extensively used. A phenomenal development in the uses of electricity has also taken place in the United States within the last decade. In no city has this development been more significant than in Chicago, where electric energy for all purposes, municipal, transportation, industrial and domestic, is now supplied by a single corporation. The union, into a single system, of classes of service which in many other cities are segregated gives Chicago many advantages. Power which might be developed in a number of small plants is developed in a few large plants made up of units of the largest size and highest efficiency. Energy for all purposes is delivered by a single distributing system. The load factor of the generating stations and of the distributing system profit by the diversity of service rendered. These are all conditions which make for efficient service.

The effect of extending the use of electricity as a means in smoke abatement is an indirect one. Except where water power is available, electric energy is normally the product of steam power. Outside of a limited amount of electric energy which is generated and distributed by the Sanitary District of Chicago, all electricity used in Chicago is of steam origin. The generation of electricity sustains a great fuel consuming industry. Disregarding all questions of relative efficiency, coal which under other circumstances would be required to sustain many small fires, is under electrification consumed by a few large fires. The gain in the abatement of smoke is in the concentration of effort. The larger establishment can be more efficiently conducted than can many small ones and the discharge of visible smoke from the large plant will be less and the solid constituents of the smoke less sooty and oily and consequently less objectionable than those discharged from many small fires.

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[*] Sir George Livesey," Domestic Smoke Abatement." Journal Royal Sanitary Institute, Vol. 27, 1906-7.

[†] R. H. Fernald, "Features of Producer-Gas Power Plant Development in Europe." United States Bureau of Mines, Bulletin 4, 1911.

[‡] A. P. Haslam, "Electricity in Factories and Workshops." London, 1909. —"Central Electric Light and Power Stations." Special Reports of Bureau of Census, 1910.—"Electricity as a Factor in Civilization." Scientific American Supplement, 1912.

101.28 Methods for Effecting an Improvement in Combustion: Since the world's available supply of bituminous or smoky coals is much greater than that of the so-called smokeless fuels, it is evident at once that any satisfactory solution of the smoke problem must effect the reduction to a minimum of the smoke arising from the combustion of bituminous coal. This in turn depends chiefly upon the proper construction, installation and management of the furnaces in which such coals are to be used.

In much of the literature relating to the production of smoke from bituminous coals a distinction is made (1) between furnaces of steam boilers and other furnaces, (2) between furnaces which are hand-fired and furnaces which are fired by means of mechanical stokers, and (3) between furnaces with auxiliary smoke appliances and furnaces not equipped with such appliances.

In general, it is evident that greater attention has been paid to steam boiler furnaces than to those of other types. Other forms include metallurgical furnaces and those used for brick kilns, coke ovens, potteries, bakeries, breweries and rendering processes. The furnaces of private dwellings also are recognized as constituting a prolific source of smoke, but the means and methods of smoke prevention for such furnaces seem to have been studied with much less care than have those applying to steam boiler and other industrial furnaces.

Smokeless combustion of bituminous coal, as defined by present practice, involves compliance with certain well defined principles, the more important of which may be described as follows:

1. The fresh coal should be introduced into the furnace at such a point and distributed in such manner that the gases distilled from it will be required to pass over the incandescent portions of the fire. Observance of this condition exposes the distillates to high temperatures, aids in their ignition and thereby promotes their combustion. The distillates, if not thoroughly burned, are prolific sources of smoke.

2. The stream of gases arising from the fresh fuel must be heated as quickly as practicable and must be kept at a high temperature until the process of combustion is well advanced. The presence of a fire-brick arch under which the distillates may be burned is an aid in securing this condition.

3. The interposition of heat absorbing surfaces in close proximity to the fresh coal or the burning distillates tends to cool the gases, to suppress combustion and to produce smoke.

4. The admission of air, by which combustion is stimulated, should be provided for at proper points and should be subject to careful regulation.

5. The proportions of the furnace should be such as will provide an ample flameway. This condition is necessary in order that the time occupied by the gases in passing through the furnace may be sufficient to permit them to burn completely. Where the length of the furnace is limited, the flameway may be extended by the use of baffle arches which require the gaseous stream to meander through the furnace, producing in effect an elongation of the flameway and promoting the mixing of the gases. A brick arch in the comparatively small furnace of a locomotive serves to increase the length of the flameway, promotes the intermixing of gases and maintains the temperature required for igniting the gases.

6. Where the dimensions of the furnace are necessarily restricted, and where the air admitted cannot be perfectly distributed, the use of small steam jets with induced air discharged into the furnace serves to promote the mixture of gases, and by so doing, to improve combustion. The use of such jets with induced air on locomotive fire-boxes is known to be of material service in suppressing visible smoke.

The literature of the subject clearly suggests the possibility of smokeless combustion in connection with furnaces which are hand-fired, but the practical difficulties to be overcome in securing such a result are always recognized. Good hand-firing implies the deposit of fresh coal at a point near the door of the furnace, where it must remain until its more volatile products have been distilled away. When coal thus fired has become coked, it may be pushed back upon the incandescent bed and a new supply of fresh coal deposited in its place. Good results may be expected from a furnace properly constructed, when fired in this way, but the labor of firing is greater than that attending a less careful procedure. Where high rates of combustion must be sustained, the Chicago Department of Smoke Inspection recommends what is known as the "spotting" method of firing, in which fuel is thrown on the fire without spreading. By this process the heat of the furnace cannot penetrate to all parts of the fuel at once and the volatile matter is driven off at a rate which is not beyond the capacity of the furnace to consume. A device attributed to the celebrated James Watt, and therefore one of the oldest of the auxiliary devices, is the so-called dead-plate. This device consists of a plate without openings, placed on a level with the grate at the mouth of the furnace, upon which coal is deposited for distillation before being pushed forward upon the firebed. This constitutes a coking arrangement and is regarded with general approval. L. P. Breckenridge, Director of the Engineering Experiment Station, University of Illinois, says:* "When Illinois coal is being burned in any furnace, it is essential that the volatile products of combustion should be uniformly distilled from the coal and mixed with sufficient air at high temperature. To accomplish this, particularly to maintain a high temperature, the mingling air and products of combustion must be kept away from the tubes or plates of the boiler, which are comparatively cool and which would, therefore, cool the gases before complete combustion had taken place."

To obtain entirely satisfactory results from hand-fired furnaces, certain recommendations for the guidance of firemen are laid down by different authorities. Among these are the following:

1. Fuel should be supplied to the fire periodically in small quantities. "A furnace well designed and operated will burn many coals without smoke up to a certain number of pounds per hour, the rate varying with different coals depending on their chemical composition. If more than this amount is burned, the efficiency will decrease and smoke will be made owing to the lack of capacity to supply air and mix gases."†

2. The accepted methods of supplying coal to hand-fired furnaces are four in number, as follows:

   a. The "spreading or sprinkling" method; uniform stoking of the entire surface of the grate.

   b. The "coking" method; covering the front part of the grate after pushing back the glowing coal.

   c. The "ribbon" method; partially covering the surface of the grate by stoking the entire length of the grate and only partially covering the sides, or by stoking one-half of the grate surface.

   d. The "alternate" method; used when the grate has two or more doors through which to feed the fuel.

The first method, of "spreading or sprinkling" the coal over the entire grate, has the advantage of simplicity, but does not prevent the development of smoke. The coal scattered lightly over the entire surface is distilled almost instantly. A greater amount of air is required than can be supplied through the grate. Imperfect combustion and smoke are the results. The conditions are improved with frequent and light stoking, but this is not possible in many industries.

The second, or "coking" method, results in a slow distillation of the gases. The requirement of air increases very little and can be partially or, under certain circumstances, entirely covered by the ordinary supply. As the bed of glowing coal insures the high temperature of the combustion chamber, an improvement in regard to the development of smoke can be attained by this method. But when the grate is forced and the fuel must be burned so rapidly that there is not sufficient time for the gradual distillation of the coal, this method fails.

By the third, or "ribbon" method, it is possible for the fireman to restrict the development of smoke if full utilization of the fuel is taken into consideration. This method requires great skill and constant care to insure combustion that is economical.

In the fourth, or "alternate firing" method, fuel is fired alternately on different portions of the grate. When fresh coal is thrown on one part the other remains incandescent. Naturally the stoking must be done at short intervals. An influence is exerted on the development of smoke in two ways. The amount of smoke after stoking seems less because it is more evenly divided over a given period of time, and excess air can enter the combustion chamber through the incandescent portion of the layer of coal, which aids the combustion of the gases distilled on the freshly coked surface and diminishes the development of smoke. Nicholson says:‡ "In my opinion (and experience has proved the truth of it) the most sensible, scientific and profitable system of firing is side firing, feeding one side of the furnace, allowing time for the incandescent fire on the other side to consume the gases before it is fired. The firings must also be light and frequent, then there will be no preventable smoke emitted, less coal burnt, and more work got out of the boilers." As to the question of the proper thickness of the firebed, opinions differ.

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* "How to Burn Illinois Coal Without Smoke." University of Illinois Engineering Experiment Station, Bulletin No. 15, 1907.

† United States Geological Survey, Bulletin 373, 1912.

‡ "Smoke Abatement." Journal Royal Sanitary Institute, Vol. 24, 1903-04.

101.29 Mechanical Stokers: The preceding statement emphasizes the advantages of mechanical stokers which automatically control the introduction of fuel into the furnace in a manner which conforms to the requirements for smokeless combustion, as already defined. "It is clear," says Popplewell,* "that there are many disadvantages in feeding boilers by hand, both as regards economy and smokelessness. The [hand] stoking must of necessity be intermittent, and consequently the air supply must also be intermittent and variable. If this air supply is carelessly regulated, smoke will be given off, in small or large quantities, or if the fire doors are left open too long or any other air supply is wrongly timed, a large amount of waste may be caused in heat carried away up the chimney. If, then, the fuel can be supplied in a continuous stream, as it were, the air must be delivered along with this fuel in a like manner, and can be regulated so as to be neither too much nor too little. This is one of the objects of feeding by means of what are known as mechanical stokers. In these the fuel is fed into the furnace by mechanical means either at very short, regular intervals of time, or in a continuous slow moving stream."

Mechanical stokers are of many different types. All are alike in that the coal is mechanically transferred from a hopper to the furnace in which it automatically progresses as it burns, until only ash and clinker remain to be discharged, or to be dumped or withdrawn at intervals. The normal automatic stoker is designed to act in conformity with the conditions already prescribed as desirable for satisfactory combustion, hence the stoker is to be regarded as a smoke preventing device. While stokers do not all possess equal merit from the standpoint of smoke abatement, those most extensively used may properly be regarded as contributing to such an end. As applied to small furnaces, stokers are chiefly advantageous as a means whereby smoke may be reduced. In their application to large plants they become labor saving devices and as such contribute to economical operation. Generally speaking, it is only when the size of a furnace exceeds that which can be hand-fired by a minimum staff of attendants, that mechanical firing becomes profitable as a labor saving measure. The precise limit at which automatic stokers will prove profitable as labor saving devices will depend upon the type of stoker and upon the conditions of service under which it is used.

Among the types of stokers extensively used, the chain grate may first be described. In this arrangement "the coal is fed from a hopper, which extends the entire width of the grate and has a plate at the back for regulating the depth of the coal, to a continuously revolving grate, the top of which is made to move from front to rear by power applied to the front or rear sprocket shaft. As usually installed, the surface of the grate is horizontal, but occasionally chain grates are given a slight incline. Beyond the hopper and extending over the whole width of the grate is a fire-brick arch. . . . In operation, coal from the hopper begins to ignite as it passes under the arch and the grates carry the burning coal toward the bridge wall at a rate which permits complete combustion before the chain passes the rear sprocket, and the refuse falls into the ash-pit below."† With a uniform load and proper setting, the smoke from this equipment is invisible; with a variable load, good results are obtainable only by "changing the thickness of the fire, the speed of the grate and the position of the damper to suit the load." The chain grate stoker is extensively and successfully used in the Middle West, where a "free burning coal, high in volatile matter, abounds." The entrance of the fresh coal under an arch, and the progressive movement of the coal, as it cokes and burns, toward the back of the furnace, are important factors in its performance as a smoke preventing device.

Roney type stokers introduce conditions somewhat similar to those for which the chain grate provides. In this type of stoker, the grate has the form of a series of steps, each one of which has a regular tilting motion. The coal is introduced from a hopper under an arch upon the first or highest step and is fed, by the movement of the steps and by pressure from the coal behind, from step to step down the flight until a flat grate at the bottom is reached. The progress down the flight is, of course, slow, and the fuel is practically all consumed when the bottom of the flight is

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* W. C. Popplewell, "The Prevention of Smoke, Combined with the Economical Combustion of Fuel." London, 1901.

† D. T. Randall and H. W. Weeks, "The Smokeless Combustion of Coal in Boiler Furnaces." United States Bureau of Mines, Bulletin 40, 1912.

reached. It will be noted that the conditions necessary to smokeless combustion are well met by this device.

Murphy type stokers introduce fuel along both sides of the furnace to inclined grates, which extend downward to a longitudinal clinker grinder at the bottom. A brick arch extends over the entire furnace. The device provides for the progressive movement of fuel into and through the furnace, for the automatic discharge of clinker and ash and for the maintenance of high furnace temperatures.

The underfeed stoker is one in which fresh coal is fed from a hopper to a retort underneath the fuel, which is already ignited. An underfeed stoker much used under stationary boilers is usually installed with automatic control of air as well as of coal. The Crawford locomotive stoker represents a successful application of this type to locomotive service. "The air and the distilled gases are intimately mixed and heated by rising through the incandescent coal so that combustion is complete within a very short distance from the retort. Hence the combustion space required over the fuel bed is less than with any other type. . . . Having the advantage of positive draft, the underfeed stoker . . . responds with ease and economy to the requirements of a variable load."* An underfeed stoker used in locomotive service has been found to work effectively with certain fuels without the use of a blower.†

The stokers thus far described belong to the so-called coking type, the principle of which involves, first, the distilling and burning of the volatile matter in the coal, and, second, the burning of the solid matter by means of the heat generated in the combustion of the volatile materials.

A type of stoker sometimes described as a sprinkling stoker is used in this country chiefly on locomotives. This stoker spreads fresh coal directly upon the surface of the fire. It is in effect merely an automatic shoveler. It serves in the development of more power than can be produced by hand-firing but it fails to introduce all of the conditions necessary to smokeless combustion.

The down-draft furnace involves the use of two grates, one above the other. The upper grate consists of a series of water tubes. The fresh fuel is thrown upon the upper grate where it is exposed to draft action so arranged that the air passes through the fuel from top to bottom. The distillates from the fresh coal at the top of the fuel bed pass through the incandescent fuel below and are ignited and in part burned in the passage. Partly burned fuel which may drop through the upper grate burns on the lower grate. The heat from the lower grate aids also in burning the gases drawn downward from the fuel above. Deflection arches or mixing piers provide for the more positive mixing of gases.

101.30 Mechanical and Physical Aids to Combustion: Steam jets, with or without induced air directed into the furnace, aid in intimately mixing the gases of the furnace, including the air, and by so doing tend to improve combustion. If used without induced air, the effect of such jets is purely mechanical. The general verdict appears to be that unless used sparingly the steam jet is not an economical device. Its first cost is comparatively slight,‡ but the amount of heat required to generate the steam for the device must be deducted from that supplied by the furnace. A very serious objection to the steam jet is said to lie in the fact that its proper use depends almost entirely upon intelligence and care on the part of the fireman, though sometimes it is installed so as to be automatically thrown in and out of service. According to R. P. King,¶ consulting engineer, "Steam jets are not adapted for boilers larger than 125 horse-power nor should they be used when more than three boilers are connected to one chimney." "Whatever may be their theoretical merits," says one inspector,§ "a constant repetition of the excuse, 'The fireman forgot to turn on the jets,' almost tempts me to condemn steam jets unreservedly."

The brick arch in a furnace aids in maintaining a high temperature of flame. There are many different arrangements involving the use of the arch. In stationary boilers with stokers, it is located above the fire at the initial end of the furnace, where it acts to conserve the heat of the coolest portions of the grate. "In hand-fired boilers, it may with profit be located back of the

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* D. T. Randall and H. W. Weeks.

† Crawford Locomotive Stoker.

‡ D. T. Randall and H. W. Weeks.

¶ "Municipal Control of Smoke." Engineering News, Vol. 54, 1905.

§ St. Louis Smoke Inspection Report, 1909.

bridge wall, where it supplies a zone of high temperature into which the gases must pass on their way to the boiler."* In locomotive furnaces, it is inclined over the fire from front to rear, where it serves to reflect the heat and the rising gases into the fire. It is sometimes so constructed as to admit an auxiliary supply of air needed to complete the combustion of the gases as they pass from under it. The brick arch is not in itself a smoke consumer, but its presence aids in the suppression of smoke.

Baffle walls are much used to prevent too direct and swift a movement of hot gases from the furnace, and thereby to secure their full utilization.

"Forced" or "induced" artificially stimulated draft is employed in many forms of furnaces. Its presence may be assumed to insure a better control of air distribution in the furnace than can otherwise be had and hence to promote satisfactory combustion. According to Nicholson,† mechanical draft as an adjunct to steam boiler furnaces has many advantages, among which are the following: It increases the steaming power of the furnace; it enables the utilization of an inferior and cheaper fuel; it supplies a steady draft regardless of weather conditions; and it allows thicker fires than can be used with natural draft. Reports from numerous smoke departments indicate differences in opinion concerning the value of mechanical draft as a means in smoke abatement. While it may aid in smoke prevention, it is likely to occasion a dust nuisance quite as serious as the smoke nuisance.

Certain chemical devices have at various times been proposed and used as a means in smoke prevention, but to these comparatively little importance can be attached. They provide for mixing with the fuel materials presumably rich in oxygen. Nicholson speaks with approval of one of these processes. It does not appear, however, that any such procedure has as yet attained the dignity of approved practice.

101.31 Conclusions: This review of the literature relating to mechanical, physical and chemical means of abating smoke shows:

1. That among the means which have been suggested to reduce the amount of smoke in the atmosphere of cities are:

    a. The removal of fuel consuming industries to points remote from the city.

    b. The construction of smoke sewers, or community chimneys, of such size and height as to permit of directing the discharges from many flues into one stack and thereby delivering the combined stream far above the city.

    c. The establishment of central heating and power plants combining the activities of many small coal consuming plants into a few large centers which may possibly be located at points removed from areas of congested population.

    d. The employment of devices for washing smoke discharges before emission into the atmosphere.

    e. The condensation and deposition of smoke particles by means of electric devices.

    f. The abolition of many small coal fires through an extension of the use of gas and electricity.

    g. Improvement in methods of firing.

2. That fires of bituminous coal may be maintained without becoming sources of visible smoke, providing certain principles are recognized in the design of furnaces and in the manner in which they are fired.

3. That it is possible to secure smokeless combustion of fuel in fires under stationary boilers by hand-firing, though such a result implies careful supervision.

4. That many types of automatic stokers are available, the operation of which, under favorable conditions, is unattended by the production of visible smoke.

5. That various aids to combustion are recognized which, when applied to furnaces, tend to suppress smoke. The more important of these are:

    a. The brick arch as applied to stationary boilers and as applied to locomotive boilers.

    b. The use of baffle walls in furnaces.

    c. The use of the steam jet with induced air for accelerating the process of combustion.

EFFECTS OF SMOKE UPON HEALTH

101.32 Character of Available Data: The influence of smoke in the atmosphere upon health constitutes a question which has been much discussed. The testimony as it appears in existing literature is conflicting. All that may be accomplished by a review is to present a true reflection of this testimony and to emphasize the facts which may be accepted as reliable evidence.

As early as the year 1844, a writer in the *Mechanics' Magazine* declared: "I know that black coal smoke is about the least injurious to health or vegetation of any volatile product of our

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* Osborn Monnett, Communication to the Committee, Oct. 3, 1914.

† W. Nicholson, "Smoke Abatement, A Manual," p. 162, London, 1905.

chimneys." Delahaye,[*] commenting in 1899 on the report of the Leeds Commission, stated: "In spite of the abundance of smoke, people are no worse off in Leeds than elsewhere. Façades of houses are soiled, but the inhabitants do not suffer. Are we going to learn one of these days that smoke, thanks to its antiseptic properties, contributes to making the atmosphere healthful? After having proscribed smoke because it promotes bronchitis and other diseases of the respiratory organs, will we demand its reinstatement because it destroys germs and microbes?" In a letter to the Smoke Conference of the Franklin Institute of Philadelphia, the late Dr. R. H. Thurston, Head of Sibley College of Engineering of Cornell University, wrote: "I do not mean to intimate that the 'smoke nuisance' endangers health in any ordinary case; on the contrary, I am inclined to think that the presence of this, which is always a minute amount of free carbon in the air, is rather healthful than otherwise."[†] The city of London, notorious for its smoke and yet healthy, is often cited as furnishing proof that smoke is not injurious.

Among those who contend that smoke is injurious to health, Dr. J. Nowak,[‡] of Vienna, writes: "In former times, some went even farther and attempted to prove that smoke is actually sanitary for large, densely populated cities, because it destroys the contagia and miasmata which are developed in sewers, canals, waste matter and refuse water. At the present time, since our ideas of infection and disinfection have undergone an entire change, we know that this idea was wrong." Dr. A. Jacobi,[¶] of New York City, after reviewing the experiments of Ascher, Klebs, Bartel and Neumann as to the injuries caused by coal smoke, says: "A serio-comic contrast is furnished by the opinions of those who assert that soot in the lungs prevents tuberculosis." Similar views are expressed by Coullaud, Fodor, Graham, Orsi and F. A. R. Russell.[§]

The effects of smoke on health, whether injurious or beneficial, may clearly be either direct or indirect, and if direct, may be due to one or more of its constituents separately or to all in combination.

101.33 The Effects of Soot and Dust upon Health: Of all diseases of the lungs due to the habitual inhalation of minute mineral or metallic particles, those caused by coal dust in mines have been the longest known and the most carefully studied.[**] The diseases due directly to coal dust are dyspnœa (difficult breathing), chronic catarrh and emphysema (distention of the air passages with obliteration of the air cells).

Dr. Oskar Klotz[††] states that definite observations upon the presence and nature of pigment within the lung substance and its associated lymphatic structures are of relatively recent date. Nevertheless, as early as 1717, Ramazzini discussed the presence of carbonaceous material within the lung and indicated an association with definite pulmonary diseases. Pearson, in 1813, followed by Laennec, in 1819, studied the problem and applied the term anthracosis or coal miner's lung. Pearson's contention that individual coal particles when inhaled become deposited in the lung tissue was supported by Gregory, but strongly combated by Koschlakoff, Virchow and Henele and, as late as 1855, by Barthelmess. Subsequently, however, Pearson's observations were confirmed in Traube's clinic (1860), where some carbon pigment, presumably having its origin in charcoal, was demonstrated in the lung substance. Since then the deposition in the lungs of carbon from smoke has been amply confirmed by studies upon human lungs as well as by animal experimentation. In the early days of cellular pathology, extensive pulmonary anthracosis rarely occurred and intensive examples of pigmentation of the lung were found only among coal miners. Today the use of coal has become so general, as the main source of energy for the remarkable industries which began in the middle of the 19th century, that in every city the air is more or less polluted by carbon particles, and few persons living in such smoke polluted cities can escape the accumulation of carbon particles in the

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[*] "A propos des fumées industrielle et autres." (Industrial and Other Smoke.) Revue industrielle, Nov. 4, 1899.

[†] "The Smoke Nuisance and its Regulation." Journal of the Franklin Institute, Vol. 143, p. 393, 1897.

[‡] "Der Rauch in gesundheitlicher Beziehung." (Smoke in its Relation to Health.) Wiener medizinische Wochenschrift, 1881.

[¶] "Smoke in Relation to Health." Journal of the American Medical Association, Vol. 49, p. 813, July–Dec., 1907.

[§] Consult the works under these names in the Bibliography, Appendix, section 701.59.

[**] Dr. Racine, "Ueber das Verhältnis von Emphysema und Tuberculose zur Kohlenlunge der Bergleute." (On the Relation of Emphysema and Tuberculosis to Coal Lungs in Miners.) Vierteljahrsschrift für gerichtliche Medizin, Vol. 40, 1884.

[††] "Pulmonary Anthracosis—A Community Disease." American Journal of Public Health, Vol. 4, 1914. Research carried on in conjunction with the smoke investigation of the Mellon Institute, University of Pittsburgh.

respiratory system. Dr. Klotz made a series of autopsies upon persons who had been residents of the Pittsburgh district for the greater part of their lives, but who had not been engaged in coal mining, for the purpose of ascertaining the gross pathological changes which arise from the excessive inhalation of carbon laden air. He summarizes the results of his observations as follows:

> "Pulmonary anthracosis (not in coal miners) is distinctly an urban disease, and is proportionate to the smoke content of the air.
>
> "The soot is inspired and lodges in the pulmonary alveoli from which it is carried by phagocytes into the lung tissue to become lodged in some portion of the pulmonary lymphatic system.
>
> "Although small quantities of carbon deposit in the lung may remain without harm, yet the quantity accumulating in the dweller of the larger cities has an accompanying greater or less fibrosis impairing the elasticity as well as altering the functional capacity of the organ.
>
> "The distribution of carbon is fairly uniform in the parenchyma of the different lobes, but there is a considerable variation in the distribution of the pleural deposit. The interlobar and diaphragmatic pleural surfaces show the least pigment. Moreover, less pigment is found in the grooves produced by the ribs or abnormal bands.
>
> "Carbon tends to accumulate at the nodal points of junction of the lymphatic channels. The cellular migration of carbon may lead to unusual accumulations in certain areas particularly well demonstrated in the deposit about chronic tuberculous lesions.
>
> "Carbon deposits, by inducing fibrosis, tend to encapsulate chronic tuberculous foci.
>
> "Pulmonary anthracosis by itself does not appear to stimulate the production of pleural adhesions.
>
> "The actual amount of carbon present in the lungs of different individuals varies considerably and is dependent, in part at least, on the age, occupation, residence, and condition of the lungs (emphysema, collapse, tuberculosis)."

Dr. Seltmann[*] concludes that the deposit of coal in the lungs diminishes the gaseous exchange by decreasing the breathing surface, checks the formation of blood and so causes anemia and dyspnœa. Dr. Merkel[†] thinks that emphysema originates from chronic bronchial catarrh, but as catarrh is very prevalent among miners and emphysema very uncommon, Racine denies the connection and ascribes such cases of emphysema as occur in mines to the direct effects of the coal dust. "With every inspiration in air filled with coal dust, fine particles of coal enter the lungs and clog them. Every following breath brings new air, which cannot get into the clogged alveoli but must seek out other parts of the lungs. If the ribs are elastic enough and the active processes of respiration ample, then the inspired air will be sufficient in quantity to overload the alveoli which can be used and will thus gradually enlarge them. . . . The men who work in the current of outgoing air are the very ones who contract the disease most easily—and it is here that the air current contains the greatest number of coal particles."

The relation of "coal-lungs" to tuberculosis has been widely discussed. Many authors contend that tuberculosis is very rare among coal miners, and ascribe its rarity to the antiseptic properties of coal.[‡] This is denied by Schlockow and by Dr. Louis Ascher.[¶] Ascher cites English statistics to show that the low mortality from tuberculosis among laborers breathing coal dust is confined to miners and concludes from his study of such statistics that:

> 1. Coal dust does not retard the development of tuberculosis.
>
> 2. The low mortality among miners from tuberculosis is due to the fact that they are a picked class of men, better paid and of a higher cultural level.
>
> 3. Smoke and soot cause a tendency toward acute lung diseases and cause tuberculosis to run its course more quickly.

Racine contends that few if any of those who have discussed the subject have distinguished with sufficient care between tuberculosis and other pulmonary diseases, such as chronic pneumonia. After careful analyses of many cases represented as tuberculosis, he reports that "very seldom did the diagnosis show the case to be pure tuberculosis," and that, although tuberculosis is very prevalent among the wives of the miners, it is seldom found among the miners themselves. He rejects Schlockow's suggestions attributing the immunity of the miners to the high location of their dwelling places and the sinking of the level

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[*] "Die Anthrakosis der Lungen bei den Kohlenbergarbeitern." (Anthracosis of the Lungs in Coal Miners.) Deutsches Archiv für klinische Medizin, 1866-7.

[†] "Krankheiten die durch die Inhalation einer jeden Art von Staub hervorgerufen oder gefördert werden können." (The Diseases Due to the Inhalation of Dust.) v. Ziemssens Handbuch der Speciellen Pathologie und Therapie, 1874.

[‡] Dr. Racine, "Ueber das Verhältnis von Emphysema und Tuberculose zur Kohlenlunge der Bergleute." (On the Relation of Emphysema and Tuberculosis to Coal Lungs in Miners.) Vierteljahrsschrift für gerichtliche Medizin, Vol. 41, 1884.

[¶] On this point, Ascher's results are summarized in his paper, "Die Einwirkung von Rauch und Russ auf die menschliche Gesundheit." (The Effects of Smoke and Soot upon Human Health.) Deutsche Medizinische Wochenschrift, Vol. 35 1909.

of the ground water in these neighborhoods, and supports the view of Wahl[*] and Fincke[†] that coal has a great disinfecting power and that it acts as a hindrance to the growth of bacilli in the lungs.

B. A. Cohoe[‡] quotes the following: "Oliver thinks that soot acts in a manner different from coal dust. 'Soot,' he states, 'increases the action of incipient tuberculosis, whereas coal dust has an unfavorable effect on the tubercle bacilli. Soot has only a mild action in preventing infection by tuberculosis, whereas coal dust is active in its immunizing qualities. The acid elements of the soot are not only an irritant, but an aid to tuberculous development. . . . It is a common experience that the course of pulmonary tuberculosis is hastened by living in a smoky atmosphere, also that smoke predisposes to acute lung diseases. Soot differs from coal dust in being a spongy material capable of absorbing sulphuric acid and hydrochloric acid up to 10 per cent, besides retaining other free acid gases and certain oxidation products of a tar-like nature.'

"According to Lehman, the sulphur dioxid contained in soot is absorbed by the nasal mucous membrane and the particles of carbon are carried further into the respiratory passages, and are finally deposited in the lung tissue, having meanwhile in their descent given up to the bronchial mucous membrane and the lining membrane of the lungs some of the acids which they retained.

"Cornet, by means of animal experimentation, demonstrated that soot did not contain any qualities which would stop or inhibit the tuberculous process."

Experiments to determine the direct effects of smoke and soot on dogs and rabbits have been conducted by several investigators. The most notable of these are the experiments of Dr. H. Ruppert,[¶] Assistant Physician in the Polytechnic Institute at Heidelberg, Germany, made primarily with a view to discovering how and in what form soot penetrates into the tissues of the respiratory organs and what changes it produces in them. His conclusions are to the effect that even weak animals can breathe an atmosphere thick with soot from a petroleum lamp "for weeks without injury" and that "no change is caused in the bronchi by the inhalation of a chemically indifferent dust."

It appears to be an accepted fact that mineral dust, which is often an accompaniment of smoke, is more injurious to health than is carbonaceous dust. Sir James Crichton Browne[§] says that "carbonaceous dust seems to be least injurious to the human organism. . . . Besides being in some degree antiseptic, carbon dust is less irritating and scarifying than many other industrial dusts, and it is really by their irritating and scarifying power that the lethal effects of dust are to be measured." Dr. Evans,[**] of Chicago, writes: "Smoke carbon is probably as little harmful as any solid which can be taken into the human body. It is quite inert chemically. Physically, it irritates but little. The harm that it does is that it transports bacteria and secures entrance for them where alone they would be repulsed."

It is of interest to note that upon one fact all authorities seem to agree, namely, that soot and coal dust, as Dr. Ruppert has shown, do not make their way into the lung tissues by piercing or boring; that although coal dust produces emphysema of the lungs, it does not produce irritation.

The mortality of occupations which are known to be particularly dusty is notably higher than that of occupations of the opposite character. An English statistician, Dr. Tatham, of Manchester, quoted by Sir James Crichton Browne, compiled a table of 22 dusty industries, showing that in each of them "the mortality from tubercular phthisis and respiratory diseases together is more than double that of agriculturists. . . . A detailed examination of the conditions of work in each of the 22 principal dusty trades brings out clearly that it is the dust that is primarily at fault in causing their unhealthiness, for there is always a relation between the death rate and the quantity and quality of the dust." Dr. Browne also made a special study of effects of ganister dust,[††] in connection with which he

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[*] Dr. M. Wahl, "Zür Tuberkulosenfrage." (The Problem of Tuberculosis.) Centralblatt für allgemeine Gesundheitspflege, 1883.

[†] Dr. Fincke, "Die Kohle als Antisepticum." (Coal as an Antiseptic.) Deutsche Medizinische Wochenschrift, pp. 685 ff, 1883.

[‡] "The Relation of Atmospheric Smoke and Health." Bulletin No. 9, Smoke Investigation of the Mellon Institute, University of Pittsburgh, 1914.

[¶] "Experimentelle Untersuchungen über Kohlenstaubinhalation." (Experimental Investigations of the Inhalation of Coal Dust.) Virchow's Archiv, Vol. 2, 1878.

[§] "The Dust Problem," Journal Royal Sanitary Institute, Vol. 23, 1902.

[**] Quoted by Cohoe.

[††] Ganister is a hard, silicious rock used in lining furnaces. It has no specifically poisonous properties.

states that ganister "kills, not by inducing phthisis in the primary sense of the term, although that is the commonly certified cause of death, but by setting up more or less wide-spread fibrosis in the lungs. . . . The hard, angular, piercing particles drawn into the bronchi and pulmonary air cells by repeatedly recurring irritation, set up hyperplasia of the connective tissue, which is perhaps an attempt at repair; the newly formed fibrous tissue, with the progressive stimulus characteristic of all infant growth, extends beyond the original seat of lesion, compresses surrounding tissues, causing degenerative changes, and ultimately compromising the functions of the viscus and exposing it to attacks of infective organisms. . . . The likelihood is that all kinds of dust that act mechanically set up changes in the lungs analogous to that induced by ganister dust."

101.34 Effects of the Gaseous Elements of Smoke upon Health: Each of the more important gases of combustion represented by the carbon and sulphur compounds is generally regarded as injurious to health when present in the atmosphere in sufficient quantities. Investigators are, however, not in agreement as to the extent of the effects produced by the normal content of these gases in the air of cities.

Carbon monoxid is a product of incomplete combustion. Under normal furnace conditions it is either lacking in smoke or appears only in small amounts. It is known to be extremely poisonous. Man is more susceptible to its influence than are the lower animals. Dr. H. Coullaud states[*] that the effect of carbon monoxid inhalation by firemen is not, as a rule, very serious. He estimates that the gaseous mixture inhaled must contain at least 15 per cent — ten times as much as is contained in ordinary smoke — in order to produce immediately harmful effects. Dr. J. von Fodor,[†] after reviewing the results obtained by previous investigators and reciting his own experiments, sums up his hygienic conclusions as follows:

> 1. If the carbon monoxid in the air breathed exceeds 0.15 per cent it is dangerous to health.
> 2. If it is breathed for a considerable time in greater quantities than 0.05 per cent it is injurious to health.
> 3. If it is diluted up to 0.004 per cent it is still taken into the organism; therefore it should be excluded above this limit, and where possible also below it, from the air of our dwellings.

While carbon monoxid is often present in dangerous quantities in crowded and poorly ventilated rooms or in rooms heated with ill-constructed stoves, investigators show that it is present only in minute amounts in the atmosphere even of smoky cities. According to A. Gautier, the amount of carbon monoxid in air does not exceed one part in 500,000, or 0.0002 per cent, an amount too small to endanger health. Seidell and Meserve[‡] affirm that a review of the available literature upon the physiological effects of small amounts of carbon monoxid and sulphur dioxid shows that, in order to produce an unmistakable harmful effect upon man, these gases must be present in the air in amounts exceeding the maximum found by them in any tunnel-air sample.

Carbon dioxid is a necessary result of complete combustion and all smoke is heavily charged with it. It is "not very poisonous," according to Coullaud, "for Pettenkofer passed several hours in an atmosphere containing one per cent of it without experiencing any ill effects and Forster breathed, without difficulty for ten minutes, air in which there was four per cent." In factories an average of 10.1 volumes per 10,000 of carbon dioxid has been found in the daytime and 17.6 per 10,000 at night when gas was burning. In elementary schools in Dundee, Scotland, the average proportion of carbon dioxid was found to be 18.6 volumes per 10,000 with natural ventilation and 12.3 volumes with the indifferent mechanical ventilation sometimes employed.[¶] The effects in both factories and schools were doubtless deleterious but not immediately poisonous. In normal country air, however, the proportion of carbon dioxid is about 0.03 per cent (three parts in 10,000), and in city air, as already shown by the review set forth in preceding sections, it is frequently as low as 0.03 per cent, is rarely above 0.04 per cent and, so far as the records indicate, never exceeds 0.05 per cent. The effect of the amounts usually found in city air is, according to Rubner[§] and others, inconsiderable.

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[*] "L'intoxication par les fumées chez les sapeurs-pompiers." (Poisoning by Smoke among Firemen.) Annales d'hygiène publique et de médecine légale, 4th Series, Vol. XII, 1909.

[†] "Das Kohlenoxyd in seinen Beziehungen zur Gesundheit." (Carbon Monoxid in its Relation to Health.) Vierteljahrsschrift für Gesundheitspflege, Vol. 12, 1880.

[‡] "Gaseous Impurities in the Air of Railway Tunnels," 1914.

[¶] John S. Haldane, M. D., "Air of Factories and Workshops." Journal of Hygiene, Vol. 2, 1902.

[§] "Ueber trübe Wintertage." (Cloudy Winter Days.) Archiv für Hygiene, Vol. 59, 1906.

"Evans believes that we can stand a much higher percentage of carbon dioxid than is ever found in the outside air and that, while carbon monoxid is directly toxic, carbon dioxid is only depressant and remotely toxic, and is never fatal in 'one whiff in any concentration.' But, as he wisely adds, 'neither does a child get a complete education in five minutes in a grammar school.'"*

Sulphur compounds in smoke result from the presence of sulphur in the fuel. The amount of such compounds liberated per unit weight of fuel consumed is a function of the characteristics of the fuel. The effect of the sulphur compounds upon health has been studied by numerous investigators. Dr. T. W. Schaefer† after ten years of investigation reached the conclusion that sulphur dioxid in the atmosphere is "one of the most potent causal factors of asthma." Cushny states, as quoted by Dr. Schaefer, that sulphurous acid produces irritation of the mucous membranes and that sulphur anhydrid, which is still stronger in its effects, acts, even when present in amounts as small as five parts in 10,000, "as an irritant, causing sneezing, coughing and lachrymation, and in somewhat greater concentration it becomes entirely irrespirable," while "still smaller quantities in the air cause bronchial irritation and catarrh when inhaled for some time." By experimentation upon guinea-pigs, rabbits and pigeons with sulphurous acid, Enrico Ronzani‡ found that, as a result of 30 days' exposure, the weight of the animals had decreased but that the number of red corpuscles in their blood had increased. Of the 42 animals experimented on in the 30 days, however, only three died from the effects of the acid.

According to Cohoe, "it is probable that sulphurous fumes are the most deadly of all the gaseous constituents of smoke. In this connection Evans states: 'Sulphur compounds are very objectionable and probably more harmful than carbon compounds. Probably before long our dense smoke ordinances will be changed so as to add to the carbon control other provisions which will control sulphur compounds. Possibly, also, the combustion experiments will likewise be directed more to the solution of the sulphur problem.'"

While some smoke may have other constituents, those which have been considered comprehend all that is significant in the output of normal furnace fires. Certain investigators express the view that the only constituents of smoke diffused in city atmosphere which may possibly be injurious to health are "mineral dust" and "sulphur compounds"; but conclusive evidence that these constituents in the diluted form in which they appear in the atmosphere of even a smoky city are actually injurious, is lacking.

101.35 Direct Effects of Smoke as a Whole upon Health: The effects of smoke as a whole upon health are of greater importance than are those of its separate constituents, as considered in the preceding section. The effects of smoke are often regarded as being either direct or indirect. The direct effects of smoke are those which may result directly in the promotion of disease; the indirect effects are those which may be incident to fogs, lack of sunshine or other conditions generally regarded as being intensified by smoke.

The direct effects of smoke are, it is usually assumed, to be noted in the respiratory organs. It is stated by Dr. Kister that "it is not easy to prove a direct injurious effect of smoke upon our respiratory organs." Dr. L. Heim says that, "the impurity of the air caused by the combustion of coal is detrimental to the health. That those who are in good health are directly harmed is difficult to prove. It is known, indeed, that in sooty cities deposits of carbon can be found in the lungs in increasing quantities but it has not been noticed that this has caused an increase in the death rate. Diseased respiratory organs, however, are seriously injured by smoke and soot." Dr. Tatham, the Medical Officer of Health for Manchester, stated in his report in 1890 that the working life of the people in Manchester township, which is the central part of the city, was curtailed by ten years. The average expectation of life among men from 1880 to 1890 was, it is stated, for England and Wales 43.66 years, for country districts 51.48 years, and for Manchester 28.78 years. "Our people lose 30 per cent of their lives," says Dr. Tatham. . . .

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* B. A. Cohoe, "The Relation of Atmospheric Smoke and Health." Bulletin No. 9, Smoke Investigation of the Mellon Institute, University of Pittsburgh, 1914.

† "The Contamination of the Air of our Cities with Sulphur Dioxid, the Cause of Respiratory Disease." Boston Medical Journal, Vol. 157, 1907.

‡ "Ueber den Einfluss der Einatmungen reizender Gase der Industrien." (On the Effects of Inhaling Irritating Gases of Industries.) Archiv für Hygiene, Vol. 66-67, 1908.

"The acids of smoke and carbon particles operate upon the lungs for years before they finally destroy them."[*]

Coullaud, in discussing the effects of smoke upon firemen, who are often exposed to the dense fumes of serious fires in buildings, says: "It is to be noted that in most of the large cities serious accidents are rare owing to precautionary measures taken everywhere. At Lyons, Bordeaux, Lille, Nantes, Brussels, Angers, Rome, Liverpool, Birmingham, Edinburgh, Glasgow, Vienna, Hamburg, Bremen, Hanover, Washington and Baltimore, only slight disorders have been observed. No serious maladies attributable to the absorption of smoke have been registered in the past 12 or 15 years. In Chicago no case of death has occurred from this cause for 20 years, nor have any serious disorders which have necessitated reform been established. At Amsterdam several light cases have occurred, which yielded to milk diet."

Among those who have studied carefully the effects of smoke is Dr. Louis Ascher[†] of Germany. His presentations have been extensively discussed but his conclusions have not always been adopted without qualification by other experts. In his experiments he sought answers to two questions:

> "1. Does smoke cause a predisposition to lung diseases in rabbits, that is, are rabbits which have been forced to inhale smoke for some time seized by an acute lung disease while animals not so treated are free from it, or do differences show themselves in the extension of the disease in question?
>
> "2. Does smoke cause tuberculosis to run its course more quickly, that is, are rabbits when suitably infected with tuberculosis carried off more rapidly if they have inhaled smoke than if they have not?"

The experiments performed yielded the following results: "Animals inoculated with tuberculosis vaccine and exposed 90 to 120 days (10 hours daily) to smoke died sooner than animals not so inoculated, and sooner also, on the average, than tuberculous animals not exposed so much to smoke. Animals which had breathed moderate quantities of smoke for several weeks were infected with inflammation of the lungs by breathing aspergillus, while control animals (animals which had not been subjected to smoke) were not." Ascher found that moisture combined with smoke intensified its effects. He acknowledges that not all doubts as to the assumption that smoke alone is responsible for the increase of acute lung diseases and accelerated cases of tuberculosis have been removed; a list of auxiliary causes will, he says, probably attain prominence in this matter as in most scientific questions.

Similar conclusions were reached by Ascher by means of statistical investigations. Dividing lung diseases into two classes, tuberculous and non-tuberculous, he found that the effects of diseases of the latter class were intensified by smoke and that the mortality rate for very old and very young persons, or those particularly subject to acute non-tuberculous diseases of the lungs, was greater in smoky districts than in those not affected by the smoke nuisance. General opinion as to the effects of smoke upon lung diseases had, he thought, been misguided by the fact that the rate of mortality among miners is low. By means of the distinction between tuberculous and non-tuberculous lung diseases, he states, much of the misunderstanding may be dispelled. He concludes that, "smoke causes a predisposition to acute lung diseases and makes tuberculosis run its course more quickly." The statistics upon which Ascher relied for his conclusion were drawn from mortality records of England, Scotland and Germany.

One of Dr. Ascher's tables (for 1905-09) is as follows:

	DEATH RATE PER 10,000
Death rate from acute lung diseases in all German towns with 15,000 population, or more	24.0
In equally large towns of Rhenish Westphalian industrial area	34.0
In the industrial district of Upper Silesia	36.0

It will be seen that the rate is higher in the industrial districts. Russell has utilized the following tabulation to show the extreme frequency of death due to lung diseases occurring in and about the smoky atmosphere of Glasgow in the year 1880:

Locality	Contagious Diseases	Lung Diseases	Other Diseases	Total
Rural districts	289	354	996	1,639
City of Glasgow	773	1,024	1,232	3,029
Thinly populated part of Glasgow (36 persons per acre)	450	600	870	1,920
Densely populated part of Glasgow (512 persons per acre)	1,020	1,860	1,600	4,480

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[*] John W. Graham, "The Destruction of Daylight—A Study in the Smoke Problem," 1907.

[†] "Der Einfluss des Rauches auf die Atmungsorgane." (The Influence of Smoke upon the Organs of Respiration.) Stuttgart, 1905.

Similarly, statistics compiled for Manchester reveal a strikingly high incidence of deaths from respiratory diseases. The death rate in different parts of Manchester per 100,000 for the year ending the third quarter of 1891 was as follows:

Locality	Contagious Diseases	Lung Diseases	Other Diseases	Total
Thinly populated part	241	534	954	1,729
Densely populated part	510	1,544	1,798	3,752

Dr. H. Liefmann,[*] commenting upon Ascher's results,[†] says: "Although the statistical results would scarcely be capable of giving infallible proof of the injuriousness of smoke, they have considerable weight taken together with other material; and even though a person should not be very much impressed with the animal experiments, the strikingly high mortality from acute lung diseases among miners should cause him to reflect seriously."

William Charles White and Paul Shuey, in a paper on the influence of smoke on lung infections,[‡] give the results of a series of studies in regard to the ratio between the number of smoky days and the pneumonia and tuberculosis death rate in several large cities scattered widely over the United States. They summarize the results of their investigation as shown by charts indicating the number of smoky days per year and the death rate from pneumonia and tuberculosis, as follows:

"In summing up these charts, which have been done as impartially as possible, the only constant factor which seems to have any relation is the smoke; in other words, where age of settlement, number of people per acre, and age of incorporation have any apparent influence, this influence must be coupled with the number of smoky days before any satisfactory conclusion can be drawn. It will be seen, then, that if we except Portland and St. Paul, there is a general tendency of the tuberculosis death rate to rise as the number of smoky days in the city decreases. On the other hand, it will be seen that there is a general tendency for the number of deaths from pneumonia to fall as the number of smoky days in the city decreases. In this instance, also, Portland, St. Paul and Boston must be excepted. There seems to be no definite relation, however, between the number of smoky days and the death rate under five years of age in the pneumonia group. This might readily be expected if we consider as the explanation of the influence of smoke on pneumonia the irritative changes which go on in the mucous membrane of the upper air passages as the underlying factor in this relation, and that these changes would probably take years in their production, or, as Dr. Haythorn has shown, the pneumonia difficulty may be largely one of absorption of exudate, which anthracosis by plugging the lymph spaces largely impedes.

"In general, the tuberculosis age-groups are rather uniform in their relation to each other when one comes to the study of individual influences; probably nothing is more striking than the difference between the curve for the total death rate of the white population as opposed to the colored. This is most strikingly seen in such southern cities as Memphis, Mobile, New Orleans and Richmond. There is a striking difference, also, in San Francisco and Los Angeles in the total death rate from tuberculosis, due, likely, to importation from the Middle West and northern parts of the country.

"When one studies individual cities, one finds, as in Pittsburgh, St. Louis, Cincinnati, Chicago, New Orleans and Richmond, a noticeable similarity between the total pneumonia death rate and the total number of smoky days. This is almost entirely absent in comparing the tuberculosis yearly death rate, which has persistently dropped in most of the individual cities, save the southern ones, in which there have been curious rises. It is not our intention to enter into explanation of this feature in this paper.

"We are at a loss to explain the high mortality rate from tuberculosis in Cincinnati, which seems to be out of its place in the general contour of this chart.

"In Boston, in addition to the fact that we believe it out of place from the number of smoky days from a manufacturing standpoint, Dr. Fulton had suggested in his criticism of our former paper that the high pneumonia death rate in Boston was probably due to the large number of people in the pneumonia ages (extremes of life). This our age grouping has not demonstrated, as the

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[*] "Ueber die Rauch- und Russfrage insbesondere vom gesundheitlichen Standpunkte." (On the Smoke and Soot Question, especially from the Sanitary Viewpoint.) Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, Vol. 40, 1908.

[†] See the titles of Ascher's works in the Bibliography, Appendix 701.59. Ascher's tables have been brought together in Appendix A of Cohen and Ruston's "Smoke, a Study of Town Air," 1912.

[‡] "The Influence of Smoke on Acute and Chronic Lung Infections." Transactions of the American Climatological Association, 1913. Research carried on in conjunction with the Smoke Investigation of the Mellon Institute, University of Pittsburgh.

pneumonia death rate in all ages is high in Boston. We believe that the factor which is absent in the compilation of this city is the number of smoky days in the year.

"Chicago, on the other hand, where Dr. Fulton believes there is a pneumonia obsession in the minds of the physicians, follows very closely what one would expect from the readings of the smoky days. As nearly as we can find, Chicago has been very careful, and since 1910 has forwarded its certificates to Washington, where they have been classified by the Vital Statistics Division of the Census Bureau in order to obviate the reflection of local bias.

"We believe that if it were possible to establish a reading of smoky days on the basis which Dr. Benner has established in Pittsburgh, namely, the precipitation of soot, and have this uniform in the various cities, we would be able to establish a much more intimate relation between the number of smoky days and the number of pneumonia deaths in any city."

Dr. Samuel R. Haythorn in a discussion of pulmonary anthracosis[*] reports as follows:

"Summarizing the various points indicating the disease importance of anthracosis (a condition in which carbon particles of extraneous origin are deposited in the tissues or organs, which we have gathered from histological evidence, we draw the following conclusions:

> "1. Moderate anthracosis in an otherwise normal lung is not in itself detrimental to health.
>
> "2. In tuberculosis and granulomatous conditions in which the reactions are chiefly centered in focal lesions of the tissues, the anthracotic condition is either entirely passive, or is active in assisting healing, in that it is an additional stimulus to fibrosis and encapsulation and in that it aids in the localization of the process through the obliteration of the lymph spaces.
>
> "3. In acute inflammatory conditions where the lymphatics are important for proper resolution, anthracosis becomes seriously detrimental, because of the obliteration of these spaces."

William Charles White and C. H. Marcy present the following discussion:[†]

"The chief fact which has stimulated our interest in the pneumonia problem in the city of Pittsburgh has been the terribly acute and fatal type of pneumonia which fills the wards of our hospitals. It can hardly be that this severity of infection has to do alone with the virulence of the germ; nor does it seem likely that it has to do with the generally low type of resistance which Pittsburghers have to this type of infection; rather, it seems more likely that there must be some factor present in Pittsburgh which does not operate in other cities. As we approached this subject we felt sure that we would be able to prove that this factor was the smoke of the iron and steel mills. . . .

"When we attempt to analyze the city of Pittsburgh on the basis of air content of smoke and pneumonia death rate, so striking is the correspondence between the pneumonia death rate and the smoke content of the air of the ward that we are convinced that smoke is a very important factor in the severity of the disease and that some other factor must operate in those cities where the smoke content of the air is not the determining factor in the pneumonia death rate. This correspondence is more striking even when we put in a line showing that there is no definite bearing of such other factors as poverty, race and congestion. When, however, one turns to tuberculosis and analyzes the death rate from this disease by wards and charts it in comparison with the smoke content of the air, one finds that there is no association whatever. This corresponds with our clinical observations on between four and five thousand cases of tuberculosis in the last six years. As the result of this clinical study we have come to the conclusion that the general death rate from tuberculosis in Pittsburgh is low—that there is nothing in the smoke content of the air which in any way stimulates the onset of the tubercular process or militates against the rapidity of recovery from tuberculosis when once contracted.

"In other words, after having made an analytical study of the relation of smoke in the city of Pittsburgh, where it is possible, by virtue of its contour, to separate the atmosphere into 'densely laden,' 'moderately laden' and 'comparatively no smoke' areas, and in such a way as to rule out such influences as poverty, race and congestion, we are forced to the conclusion that the smoke content of the air has an apparently

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[*] "Some Histological Evidences of the Disease Importance of Pulmonary Anthracosis." Journal of Medical Research, Vol. 29, 1913. Research carried on in conjunction with the Smoke Investigation of the Mellon Institute, University of Pittsburgh.

[†] "A Study of the Influence of Varying Densities of City Smoke on the Mortality from Pneumonia and Tuberculosis." Transactions of the 15th International Congress on Hygiene and Demography, held at Washington, 1912. Research carried on in conjunction with the Smoke Investigation of the Mellon Institute, University of Pittsburgh.

important bearing on the pneumonia death rate and comparatively little bearing on the tuberculosis death rate.

"From the careful analytical studies of the character of the smoke in the city of Pittsburgh, carried out by Dr. Klotz and Dr. Holman in connection with this same work, there is added a purely chemical and physical reason for this same conclusion, for they have found that the percentage of phenol around the carbon, which pollutes the air, is sufficient to destroy most or many of the organisms with which they have studied when suspensions of these are mixed with suspensions of air smoke.

"With this fact in mind, it is probably legitimate for one to turn to the pathological studies of these two infections. Pneumonia is a catarrhal condition, and a predisposition for it may be prepared by the irritation of the mucous membranes with foreign substances; but the second (tuberculosis), being granulomatous in type, in which the micro-organisms are sequestered and surrounded by cells, the cure of which is accomplished by fibrosis, may naturally be supposed to be aided in the direction of cure by any deposit which stimulates granulation and fibrosis. Some strength is given to this theoretical view by the evidence which we have from anatomical studies, in which we find depositions of carbon particles around the healed tuberculous focus."

Again, in his introduction to "Papers on the Influence of Smoke on Health,"* Mr. White writes: "It will be seen . . . that practically all investigators whose opinions are based on grounds other than theory, are agreed that smoke has a tremendous influence in increasing the incident severity and mortality of acute diseases of the air passages. It would appear that this increased susceptibility is, in part, the result of the lowering of our natural body resistance. In simple terms, the smokier the atmosphere, the more the colds and bronchitis, and the more money paid the doctors.

"On the other hand, the relation of smoke to tuberculosis is one of greatly divided opinion, and the burden of proof is that if smoke has any influence at all, it is not a harmful one. The work of Dr. Klotz and of Dr. Haythorn offers some explanation of this probability. If this be the truth and tuberculosis is not influenced by smoky atmosphere, it is time to stop the utterance of this popular fallacy which can do naught other than harm in sacrificing the confidence of the public in those who should guide them."

It has more than once been suggested that smoke produces its effects upon the human organism through some other channel than the respiratory organs. Renk† seems to regard the effects of smoke upon the human organism as general rather than specific, although he names certain specific effects. He says: "The gases designated as poisonous affect the bronchial passages very little or not at all, but pass through these to the blood and by this means affect the heart or the central organs of the nerves. Here also the effect is in proportion to the concentration, small quantities of gas causing slight disturbances, while larger quantities may lead to serious illness and under certain conditions, to death. . . . It is known that the lack of palatable substances in the nourishment may have an injurious effect on the digestive organs, and we may venture to assume that the impurities in the air may work in the same manner through the sense of smell, reducing the general state of health. . . . Of special importance in this connection are the investigations by Gruber, who found that carbonic oxid which combines with the hemoglobin of the blood is absorbed only in proportion to its concentration in the air. In experiments lasting several days with a uniform proportion of carbonic oxid there was no advance in the symptoms of poisoning observed soon after the beginning of the experiment, thus excluding the possibility of accumulation of gas in the body."

Of the direct effect of smoke and its constituents upon health the evidence already adduced constitutes nearly, if not quite all, that has been found on the subject.

101.36 Indirect Effects of Smoke upon Health: A favorite theme of certain advocates of smoke prevention is one relating to the deleterious effect upon health of fogs which are supposed to be due largely to smoke. Opinion, however, is not undivided even among English experts. Dr. W. J.

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* Bulletin No. 9, Smoke Investigation of the Mellon Institute, University of Pittsburgh, 1914.

† Friedrich Renk, "Die Luft" (The Air), from "Handbuch der Hygiene und der Gewerbekrankheiten." (Handbook of Hygiene and Diseases Peculiar to Certain Trades.) 1896.

Russell* of London, speaking of London fogs, says:

"By far the greater number of fogs occur when there is a great fall of temperature, and clearly this is closely followed after a few days by a great increase in the death rate; but how much of this is to be attributed to the fog and how much to the fall in temperature may be difficult to determine; but we have evidence that when fogs occur without fall of temperature, they do not appear to be followed by any remarkable increase of death rate. On December 15, 1889, there was a dense fog, and the temperature was even above the average; under these conditions the death rate remained far below the average. On December 13 and 14 in the same year again there was a dense fog, an average temperature and only an average death rate; and the same thing happened on February 4, 1890, when, notwithstanding a dense fog, the death rate remained remarkably low; and last winter, on November 13 and 14, there was a dense fog, a high temperature and an average death rate. . . . There is no case of depression of temperature not followed by increase of death rate. That many people suffer much both physically and mentally from the effects of fog there can be no doubt; but, as far as I can interpret the returns of the Registrar General, they do not confirm the popular impression that fog is a deadly scourge. . . . I think that the principal cause of the great increase of death when fogs occur is attributable rather to the sudden fall of temperature which usually accompanies fog than to the fog itself or to bacteria. . . . The experiments of Dr. Percy Frankland show that fogs do not tend to concentrate or nurture bacteria, for he found there were remarkably few bacteria in London air during a time of fog."

F. A. R. Russell,† a London meteorologist of note, expresses a view somewhat opposed to the one above stated. "Great cold combined with fog is not productive of much illness in the country. In smoky towns the case is far different. Thus, in London the death rate was raised in a single fortnight, from January 24 to February 7, 1880, from 27.1 to 48.1 per 1,000. The fatality and prevalence of respiratory diseases were enormously increased. The excess of deaths over the average in the three weeks ending February 14 was 2,994, and in the week ending February 7 the deaths from whooping cough were unprecedentedly numerous, 248, and from bronchitis they numbered 1,223. At least 30,000 persons must have been ill from the combined effects of smoky fog and cold. . . . After a fortnight of dense fog the deaths in London for one week ending January 2, 1892, exceeded by 1,484 the average number, being at the rate of 42 per 1,000. Increases took place in the following diseases:

	PER CENT
Measles	114
Whooping cough	173
Phthisis	42
Old age	36
Apoplexy	58
Diseases of the circulatory system	106
Bronchitis	170
Pneumonia	111
Other respiratory diseases	135
Accidents	103

"These results are in the main attributable to the concentration of the ordinary constituents of London air, with moisture and intense cold to help their deadly work. The majority of the fatal cases were weakened constitutions, though many were among the robust. The experience of large towns always is that the power of recovery after illness is less within their confines than in the country. In fog, the evil influences of town air are many times multiplied." In another place Russell‡ says: "The influence on life of a country fog and a London fog is shown by the death rates of London and Croydon in the great fogs of 1880; in Croydon, the number of deaths rose only from 35 to 36 in three weeks, while, in London, the number rose to 2,994 above the average."

F. A. R. Russell evidently recognizes, with Dr. W. J. Russell, the evil effects of the reduced temperature generally attending the presence of a fog, but he considers the effect of fogs upon health to be due largely to the carbonaceous element contained in them.

Dr. H. A. Des Vœux,¶ an officer of the Smoke Abatement League of Great Britain, says: "In the autumn of 1909, Glasgow was visited by two periods of smoke fog, each lasting several days

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* "Town Fogs and Their Effects." Nature, Vol. 45, 1891.

† "The Atmosphere in Relation to Human Life and Health." Smithsonian Report, 1895.

‡ "London Fog and Smoke." London, 1905.

¶ "Let There Be Light." Read at the Manchester Conference of the Smoke Abatement League of Great Britain, November, 1911.

but separated by an interval of a few weeks. During the first period the death rate suddenly rose from 18 per 1,000 to 25 per 1,000, and during the second to 33 per 1,000, although the rate in the surrounding country was hardly raised. It was calculated that 1,063 deaths were attributable to the noxious conditions."

Many students of the subject have sought to measure the injurious effects of smoke which result from its influence in reducing the amount of sunshine and light.

W. L. Holman,* in a discussion of the bacteriology of soot, gives the results of a number of experiments to determine the bactericidal action of soot:

"The great natural disinfectant of the atmosphere and our surroundings is the bactericidal action of the sun's rays. Direct sunlight is most destructive and its activity upon bacterial life depends directly on the amount of moisture and dust in the air. . . .

"Smoke, in contributing very great numbers of minute particles to the air, adds to the conditions favoring fogs and clouds. Smoke, fogs and clouds, all absorb, more or less, the blue, the violet and ultra-violet rays of the sunlight. This is well seen in the familar red sun of a smoky atmosphere. These particular rays, which are absorbed, give the important bactericidal action to the sunlight. . . . The effect of soot in fogs and clouds in diminishing the action of the sun's rays on bacteria is quite definite. The relative importance of the protective qualities of soot against sunlight to the bactericidal effect of the constituents of soot remains an open question."

The general conclusions of the discussion are as follows:

"1. Soot has a definite bactericidal action on bacteria, due either to the absorption of moisture from the organisms or more probably to the action of its contained germicidal acids and phenols.

"2. Soot as it exists in the air does not form a favorable nidus for the collection and distribution of bacteria.

"3. Broth and other fluids treated with soot have conferred upon them a decided germicidal power.

"4. This germicidal action is due not only to the acids contained in the soot but also to some other agent, probably some of the phenols.

"5. Soot, as it occurs in smoke, clouds, fogs, and as a non-transparent covering for our streets and houses, protects micro-organisms from the destructive action of the sunlight."

Ronald C. Macfie,† in discussing the effects of air and sunlight on health, expresses the opinion that the radio-activity of the atmosphere has important physiological, physical and chemical effects, and that it is quite legitimate to surmise that the radio-activity of air, as well as the radio-activity of mineral springs, has curative properties. In clear weather, he states, the air is more radio-active than in dull weather. Dr. Kister says: "The development of smoke has without doubt a bad effect upon the daylight and sunshine of a place and, because of the hygienic significance of sunshine, is inimical to our physical, or at least our psychical welfare. But it is not easy to prove a direct injurious effect of smoke upon our respiratory organs."

Dr. Niven and Dr. Kister have compiled statistics showing the mortality from certain diseases and the hours of sunshine for four English cities:‡

RELATIVE MORTALITY OF MANCHESTER AND OTHER GREAT TOWNS FROM CHEST DISEASES, AND RECORD OF SUNSHINE

Year	Phthisis				Bronchitis				Pneumonia				Sunshine (Hours)			
	Manchester	Birmingham	Sheffield	London	Manchester	Birmingham	Sheffield	London	Manchester	Birmingham	Sheffield	London	Manchester	Birmingham	Sheffield	London
1901	2.09	1.73	1.41	1.71	2.22	2.07	1.51	1.62	1.96	1.73	1.45	1.35	1192	1144	....	1567
1902	2.08	1.65	1.18	1.65	2.44	1.91	1.52	1.71	1.98	1.62	1.45	1.47	928	1048	....	1228
1903	1.85	1.45	1.36	1.62	1.87	1.73	1.71	1.15	1.87	1.48	1.58	1.28	1119	972	1216	1445
1904	1.98	1.54	1.27	1.70	1.97	2.06	1.51	1.40	2.18	1.72	1.39	1.45	1031	1239	1325	1459
1905	1.56	1.45	1.15	1.50	1.85	1.68	1.56	1.33	1.62	1.55	1.44	1.53	1005	1149	1432	1420
1906	1.71	1.29	1.05	1.53	1.74	1.68	1.46	1.18	1.59	1.47	1.32	1.45	1069	1143	1438	1735
1907	1.70	1.29	1.20	1.51	2.06	1.76	1.76	1.32	2.02	1.66	1.70	1.66	894	952	1428	1417
1908	1.65	1.39	1.28	1.44	1.96	1.73	1.95	1.15	1.75	1.35	1.59	1.46	992	981	1281	1634
1909	1.70	1.44	1.17	1.44	2.00	1.77	1.32	1.35	1.72	1.46	1.54	1.68	999	1129	1332	1641
1910	1.49	1.25	1.01	1.28	1.59	1.51	1.26	1.12	1.40	1.33	1.52	1.49	982	1011	....	1380

An examination of this table will show that, with the exception of a slight increase in pneumonia in Sheffield and London, there was a general decrease in "chest diseases" in the four cities;

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* "The Bacteriology of Soot." American Journal of Public Health, Vol. 3, 1913. Research carried on in conjunction with the Smoke Investigation of the Mellon Institute, University of Pittsburgh.

† "Air and Health," New York, 1909.

‡ James Niven, "The Relation of Smoke and Health." Paper at the Manchester Conference of the Smoke Abatement League of Great Britain, November, 1911.

but that, with the exception of London, there was no material increase in the number of hours of sunshine. The table, therefore, yields no facts which indicate that the mortality rate from "chest diseases" is a function of the amount of sunshine.

Since the city of Hamburg is one of the gloomiest of European cities, the effects there of smoke on mortality would, other things being equal, be expected to be high. The facts are presented in the following table:*

MORTALITY IN HAMBURG FROM NON-TUBERCULOUS DISEASES OF THE RESPIRATORY ORGANS
(WHOOPING COUGH AND DIPHTHERIA EXCLUDED)

Year	Under 1 yr.	1–15 yrs.	15–30 yrs.	30–60 yrs.	60–70 yrs.	Over 70	Total	% of the Dead	.01% of the Living
1894	412	305	17	143	258	173	1308	12.08	21.636
1895	559	400	22	153	289	280	1703	14.50	27.513
1896	509	377	14	152	261	224	1537	14.03	24.204
1897	417	279	20	149	260	246	1371	12.37	20.996
1898	527	389	18	139	245	255	1573	13.51	23.589
1899	405	363	27	158	339	348	1630	13.74	23.807
1900	527	414	20	218	417	1318	2914	16.50	28.935
1901	548	405	19	156	328	324	1780	14.49	24.845
1902	444	393	21	169	369	342	1748	14.55	23.854
1903	390	333	33	177	364	322	1619	12.99	21.674
1904	441	310	22	155	373	313	1614	13.37	21.081
1905	422	315	51	325	265	384	1762	14.09	22.262
1906	535	358	44	296	223	322	1778	14.24	21.768
1907	466	262	62	419	280	429	1918	15.37	22.709

The comment of Dr. Kister on these figures is as follows: "If we collect the figures for Hamburg, the table shows no decrease, or perhaps an increase in recent years, of deaths from other (namely, non-tuberculous) diseases of the respiratory organs. . . . Even though this fact cannot be referred, without further investigation, to the development of smoke, it is one of the phenomena which must be taken into account in the question of the hygienic effects of smoke."

That a perpetual or prolonged absence of sunlight or of ordinary daylight must have a deleterious effect upon health no one seems to have questioned. A theory regarding the effects in question has been put forth by the English chemist, Sir William Ramsay, who maintains the view that smoke, by directly absorbing light, by aiding in the formation of clouds and fogs which are peculiarly fitted to absorb the blue, the violet and the ultra-violet rays, the recognized germicidal elements in light, contributes to the increase of pathogenic bacteria in the atmosphere. Ramsay also maintains that there is a direct influence exerted by light upon the human body, and upon mental conditions. Liefmann, after discussing the question at some length, says, "If we group all these experiences in regard to the significance of light for our life and health, and concentrate them upon the problem which here interests us, we shall be led, in my opinion, to the conclusion that a darkening of the atmosphere of our great cities is injurious to health in three ways:

> "1. An exciting impulse which influences our disposition is weakened and the energy of metabolism, especially as it concerns respiration, is diminished.
>
> "2. The illumination and warming of the earth, the water and the air within the precincts of our great cities is diminished, and in this way a series of hygienically important processes is influenced or depressed.
>
> "3. The chemical and bactericidal effect of the sun's rays is decreased and thus bacteria, especially the pathogenic ones, are permitted to thrive.

"From this is seen the significance of Ramsay's hypothesis for the deterioration of the air in our large cities, even if it is not possible to determine exactly the degree of injury, by preference in figures. Only one question remains open, whether indeed soot plays the prominent part which Ramsay assumes, or whether there may not be other factors of equally great importance. It would seem to me as if smoke and dust were co-operative in their injurious influence upon health and that both must be held responsible for the formation of cloud and fog."

101.37 Conclusions Concerning the Effects of Smoke upon Health: The facts presented by the preceding review of the literature concerning the effects of smoke upon health justify the following conclusions:

> 1. There is a general agreement among sanitary authorities that polluted air is harmful to health.
>
> 2. At the present time there is no accurate method of measuring this harm, nor of determining the relative responsibility of the different elements which enter into the mixture of gases and solids commonly referred to as atmospheric air.
>
> 3. The direct effects of smoke or of any of its attributes, including soot, dust and gases, in amounts which may ordinarily pervade the atmosphere of a smoky city, are not shown to be detrimental to persons in normal health.
>
> 4. The direct effect of smoke upon those who are ill has been most extensively studied in connection with tuberculosis and pneumonia. It appears that smoke does not in any way stimulate the onset of the tubercular process nor militate against the rapidity of recovery when once this disease has been contracted, but that it has a direct antiseptic effect and tends to

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* Dr. Kister.

localize the disorder. In cases of pneumonia the effect becomes seriously detrimental.

5. In addition to these direct effects, indirect effects result from the diminution of sunlight and the increase in fogs, clouds and haze.

6. The general physical tone is lowered as the result of long continued breathing of polluted air.

EFFECTS OF SMOKE UPON VEGETATION

101.38 Direct Effect of Smoke upon Vegetation: The effect of coal smoke on vegetation has been investigated with results which, so far as they go, are definite. Prof. A. G. Ruston[*] has announced that the "main detrimental effects of air pollution by coal smoke upon vegetation are:

"1. The cloud of smoke blocking out the sunlight and thus, in some cases, reducing the available solar energy by 40 per cent.

"2. The thick deposit on the leaves of plants and trees still further blocking out the light.

"3. The choking of the stomata by the tarry glutinous matter, thus tending to asphyxiate the plant and effectively checking its power of assimilation of carbon dioxid.

"4. The presence of free acids in the air falling on the soil which certainly, so far as grasses are concerned, diminish the yield, make them less digestible and in other ways lower their feeding value, while they also have a very detrimental effect on the bacterial life in the soil.

"5. The presence of free acids in the air, tending generally to lower the vitality of the plant."

Statements agreeing with the above, though perhaps less explicit, have been made by other investigators, including Professor Wislicenus of Tharandt, Saxony, Miss Agar, Landscape Gardener to the Metropolitan Public Gardens, London, Dr. William Trelease, formerly of the Missouri Botanical Gardens, St. Louis, now Professor of Botany, University of Illinois, and Professor Cohen of Leeds University.

A series of extended experiments to show the effects of smoke on vegetation were made in England by Professors Crowther and Ruston[†] in 1908. Professors Cohen and Ruston[‡] of the Agricultural Department of Leeds University (England) have studied experimentally the effects of atmospheric impurities on the yield of various crops. Dr. Trelease submits the following:[¶]

"That plants are injured or killed by smoke is well known to students of vegetable pathology. Sometimes, as with greenhouse plants during a London fog, the injury is acute, the foliage wilts, becomes spotted or falls, and the plants die or have to recover condition by a struggle. With trees and shrubs it sometimes shows acute symptoms but, on the other hand, may reveal itself only in chronic weakness resulting in death after even a prolonged period of years. On the rapidity of this result the general health of the plant and its nutrition exercise an influence comparable with that noted by medical men in chronic human diseases. A critical point may thus be reached by a local increase in the smoke contents of the air in an already smoky place or in some impoverished soils.

"Different kinds of plants differ in their power of resistance to smoke poisoning, as to other diseases. Its chronic effects are easily seen on such evergreens as the spruce, fir and pine; because—aside from any question of general susceptibility—their foliage is exposed to the weather during the entire season instead of falling on the approach of winter, while its condensed form necessitates the presence of two, three or in some cases even five or six years' foliage during the season of active vegetation. With progressive smokiness of the air, especially in regions where a very sulphurous coal is used, such leaves lose their vitality after one or more years until, as is now generally true in all but the most outlying parts of St. Louis, the branches carry only one year's growth of foliage, less than one-half of their normal supply. Under such conditions, since the leaves are laboratories for the manufacture of organic food out of the normal contents of the atmosphere, it is not surprising that the trees dwindle and ultimately die."

101.39 Effect of Smoke Fogs upon Vegetation: With reference to the effect of fog, which in part may be assumed to be due to smoke, upon plants grown in the houses of the botanical garden at Kew near London, W. Watson says:[§]

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[*] "Air Pollution by Coal Smoke and its Effects on Vegetation." Paper read at the Smoke Abatement Conferences, London, 1912.

[†] Charles Crowther and Arthur G. Ruston, "Nature, Distribution and Effects upon Vegetation of Atmospheric Impurities in and near an Industrial Town." Journal Agricultural Science, London, March 25, 1911.—Also, "Smoke, a Study of Town Air," pp. 46–51.

[‡] "Smoke, a Study of Town Air," London, 1912.

[¶] Special communication from Dr. Trelease, September, 1912, Archives of the Committee, Vol. D.

[§] Dr. W. J. Russell, Appendix to "Town Fogs and their Effects." Nature, Vol. 45, 1891.

"The heavy fogs experienced in the last two or three winters injured many plants in the houses at Kew. When thick fog occurred almost daily, the injury it did to many plants amounted practically to destruction. The leaves fell off, the growing point withered, and in some cases, such as Begonias and Acanthads, the stems also were affected. Flowers, as a rule, fell off as soon as they opened or whilst in bud. Almost all flowers which expanded were less in size than when there was no fog. The flower buds of Phalænopsis, Angræcum, some Begonias, Camellias, etc., changed color and fell off as if they had been dipped in hot water. In the palm-house bushels of healthy looking leaves which had fallen from the plants were gathered almost every morning. . . . Herbaceous plants as a rule suffered most. . . . . Plants in active growth were more greatly affected than others."

101.40 Effect of Smoke upon Vegetation in Chicago: For the purpose of determining the effect of smoke upon vegetation in Chicago, a circular letter was addressed to the secretary of each of the city's park commissions, containing inquiries concerning the experience of the commission addressed in securing the development of plants and shrubs in the parks of the city.

Specific information was obtained from representatives of two commissions only. The substance of one of these is to the effect that the condition of the atmosphere in many places in Chicago is disastrous to plant life, even though the best of conditions as to soil and water supply exist. The fact is noted that on a certain boulevard, where the air is polluted by the smoke of factories and by the smoke of locomotives from a roundhouse, the result obtained in the development of trees, shrubbery and grass "is by no means as good" as it is on either side of this locality. The fact is noted also that in many places where plants were successfully grown 25 or 30 years ago, plantings have had to be given up in recent years "because of the unpropitious atmosphere."

The second response is as follows:

"In the first place, the effects of smoke, dust, soot and sulphuric gases are injurious to plant life, and the degree to which they are destructive depends upon the density of these materials and the resistant power of the plants. In the loop section, all flowering plants such as geraniums, petunias, cannas, etc., are very seriously affected, while the foliage plants such as boxwoods, coleus, crotons, pandanus, etc., will do very well. This is also true of trees and shrubs. Short lived, fast growing trees, such as poplars, willows, box elders, cottonwoods and soft maples, will survive and resist the smoke and gases more readily than the oaks, elms, hard maples, chestnuts, lindens, etc. Of course, where the trees are thoroughly syringed, and the oftener the better, so that the soot and smoke can be washed from the leaves, they will keep in better condition, but the fact remains that atmospheric pollution is destructive to plant life, and as stated above it is destructive in proportion to its prevalence and intensity and in proportion to the delicacy of the plants in question."

101.41 Conclusions Concerning the Effects of Smoke upon Vegetation: The literature of the subject shows as a result of observation and experiment, the following:

1. That smoke may exert injurious effects on vegetation. These effects may be direct or indirect. The direct effects are slow in asserting themselves, trees and plants exposed to them gradually losing vigor through a series of years until they finally perish.
2. That the products of combustion which are most pronounced in their direct effects are the soot and tar discharges and the sulphurous gases, though injury may occur as a result of an increased acidity in the soil caused by smoke.
3. That the indirect effects appear as a result of fogs induced by smoke, the occurrence of which has sometimes injured or destroyed tender plants.
4. That no basis is supplied upon which to judge the amount of smoke which is necessary to bring about injurious results; the effects described are generally such as have attended exposure to severe conditions.

LOSS AND DAMAGE TO PROPERTY

101.42 Smoke as a Source of Loss and Damage: All available literature bearing upon the subject of smoke as a source of loss and damage to property has been studied for the purpose of establishing, if possible, a basis upon which to determine, with reasonable accuracy, the extent of such damage in the city of Chicago. While such a basis has not been found, the more important facts which have been revealed are herein set forth.

101.43 Effect of Smoke upon Building Materials: The effect of smoke upon building materials has received frequent notice. Dr. Samuel Rideal, in a paper entitled "Acids of Smoke,"* states, "It has been shown by many analyses that the surface of stone buildings and outside sculptures becomes converted into a crust of sulphate, and along with the corrosion there is a roughening on which carbon settles, making the well-known black streaks or stains." Prof. H. Jackson† of King's College, London, examined certain stone which had been exposed to atmospheric pollution and submitted a report which showed the action of sulphuric acid to be responsible for appreciable disintegration. The stone in question consisted of calcium carbonate in granules, bound together by small quantities of calcium and aluminium silicate. It was noted that fairly extensive chemical action had taken place on the outside of the stonework but that the corrosion had not penetrated very deeply.

Dr. J. E. Wallace Wallin says: ‡ "Smoke defaces, disfigures or destroys buildings and restricts the styles of architecture. The sulphuric acid, particularly, corrodes or disintegrates practically all kinds of building materials (slate and granite possibly excepted). Marble tends first to turn green and then black; limestone deteriorates very rapidly, turning to gypsum owing to its great affinity for sulphur. The absorption of sulphur causes the stone to expand, thus rendering it soluble and powdery so that particles are constantly washed or blown away. The very best stone obtainable was used in the new additions to the Houses of Parliament in London, and every care suggested by modern science was taken to preserve the materials, yet the buildings were much eroded after a few years. . . . In the city of London 650 tons of soot have been deposited per square mile of ground surface, and soot deposits three-fourths of an inch thick have been scraped from cornice projections. The beauty of the architectural views consists in the distinctness of the outlines. Soot deposits conceal the artistic effects not only on stone and brick but also on wood. The difficulty cannot be entirely overcome by cleaning, because cleaning tends to remove the sharp edges and outlines. Moreover, preservatives for water-proofing often leave an unpleasant color and frequently are not effective unless 18 or 20 coats are applied (for example, of baryta-water). . . .

"The influence of smoke on metal work is equally pernicious. The sulphuretted hydrogen in smoke blackens, disfigures or tarnishes nearly all metals. Copper and bronze rapidly darken, iron rapidly corrodes, aluminum is affected by vapors and acids, many metals become pitted from electro-chemical action, and even gold or gilded articles become dull. Gilt titles on books will fade in the city while retaining their luster in the country. Bright and uneven metallic surfaces may also become coated with a mottled, sooty smear. To keep sign plates or any metal work bright and shiny requires constant work in smoky cities. The protective coatings used are not entirely satisfactory because they tend to crack or to peel off, or to leave pin holes. Constant cleaning entails large expense both because of the labor required and because of the wear on the metal. Rather than assume this added burden of expense, merchants in smoky cities tend to minimize the use of brilliant metallic ornaments. In consequence, such cities often lack that polished metallic splendor which is one of the charms of the tourist cities of the earth."

The deleterious effect of smoke upon metallic surfaces, objects of virtu and architecture is recognized as appreciable, but it has not been possible to arrive at any definite measure for such damage.

101.44 Investigations in American Cities: In 1909, a Committee on Smoke Prevention appointed by the Cleveland Chamber of Commerce presented a report of its investigation which estimated the annual financial loss to the city at about $12.00 per capita. The active work in connection with the compilation of data was confined to a period of three or four months in the spring and summer of 1909. Since then a number of American cities have conducted similar investigations, notably Pittsburgh, Chicago and Cincinnati and, while these have arrived at conclusions varying in detail from those arrived at in Cleveland, the Cleveland ratio has been the basis of comparison. The results obtained in Cleveland, however, must be accepted as suggestive only.

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* Journal Royal Sanitary Institute, Vol. 27, 1906–07.

† Cohen and Ruston, "Smoke, a Study of Town Air," 1912.

‡ "Psychological Aspects of the Problem of Atmospheric Smoke Pollution." Bulletin No. 3, Smoke Investigation of the Mellon Institute, University of Pittsburgh, 1913.

101.45 Investigations Conducted with Reference to English Cities: In London and Manchester, England, attempts have been made to estimate losses due to smoke, but in neither case can the results be regarded as satisfactory. The per capita loss arrived at was considerably lower than that of American cities, but the figures, as in the case of Cleveland, must be considered as purely suggestive.

101.46 Significance of the Results: From the study that has been made of the literature of the subject, it appears that the loss and damage caused by smoke may be divided into three general classifications:

1. Extra maintenance cost.
2. Higher depreciation.
3. Direct loss of value.

It is evident from the records that there are many variable and indeterminate factors entering into estimates covering these items. No attempt seems to have been made to separate the damage due to smoke from that due to other sources of atmospheric pollution. It is evident, also, that little if any allowance has been made, in accepting estimates of interested individuals, for the obviously natural tendency to ascribe to atmospheric pollution the deterioration due to obsolescence and decrepitude, which must be regarded as more important factors in depreciation in our large cities than in those communities where life is less complex.

101.47 Work of the Chicago Association of Commerce Committee of Investigation on Smoke Abatement and Electrification of Railway Terminals: The advisability of attempting to organize an investigation which would lead to more definite results than those developed by other investigators was considered by the Committee. A circular letter was prepared and sent to a carefully selected list of apartment house owners, agents of office buildings, wholesale and retail merchants, manufacturers, associations, schools and colleges, newspapers and periodicals, libraries, hospitals and public institutions. The list included about 800 names. The letter was not a request for data but for suggestions concerning methods to be employed in securing data. The questions asked were as follows:

1. In your opinion would it be practicable to determine with a considerable degree of accuracy, the amount of loss and damage per annum to your building and its contents, separately, caused by the products of combustion (smoke) and other pollutions of the atmosphere, as dust, dirt, fumes, etc.?
2. If (1) would be practicable, would it also be practicable to segregate the estimated amount of the loss and damage caused by smoke from the loss and damage caused by other pollutions of the atmosphere, as dust, dirt, fumes, etc.?
3. What method or system would you suggest for determining the loss and damage per annum caused by smoke (products of combustion) and by other pollutions of the atmosphere in each of the following cases?
   - *a.* Exteriors of large office or business buildings.
   - *b.* Interiors of large office or business buildings, exclusive of furnishings.
   - *c.* Furnishings of interiors of large office or business buildings.
   - *d.* Merchandise products, or articles such as you handle.

The replies to this letter were few and unsatisfactory. They served, however, to emphasize the fact that any investigation designed to disclose, with a reasonable degree of accuracy, the extent of the loss and damage resulting from smoke in Chicago would need to be elaborately organized. It appeared to the Committee that the promise of a successful issue was not such as would justify the time and expense that would be involved.

101.48 Conclusions Concerning Smoke as a Source of Loss and Damage to Property: Fullest consideration of the various phases of the entire problem as set forth by the literature of the subject and by the studies of the Committee emphasizes the following:

1. Many of the facts involved are variable or indeterminate.
2. Concerning the sources of loss and damage occasioned by smoke the following is to be noted:
   - *a.* The loss and damage caused by the gaseous products of combustion are due chiefly to their sulphur content. The investigations of the Committee show that the extent to which sulphur appears in such gases depends upon the composition of the fuel and not to any great extent upon the manner in which it is burned. Loss and damage, therefore, arising from the gaseous products of combustion are a function of the kind and quantity of fuel burned.
   - *b.* The extent of loss and damage arising from the solids in smoke will, other things

being equal, depend upon the character of the solids. For example, solids in the form of soot and oily distillates of fuel soil and deface more quickly than solids in the form of coke or ash particles. The former are characteristic of smoke from low temperature fires, such as those of domestic service; the latter are characteristic of smoke from high temperature fires, such as those of high pressure steam boilers and steam locomotives.

3. An attempt to define the extent of losses regardless of the manner in which they arise at once discloses the lack of a definite or reliable standard of measure. It cannot be assumed, for instance, that a large city ought to be as clean as a country village, nor can any ratio of cleanliness be established. It is obvious that the diversified activities of the larger communities are productive of a greater degree of street dust and other forms of atmospheric pollution, as well as of smoke, than those of the small towns. The large cities are, in most cases, more congested than the small ones, and this congestion is in itself productive of a greater degree of atmospheric pollution whether of a preventable or unpreventable nature.

4. In view of the many complex and variable factors involved, any attempt to secure an accurate or satisfactory solution of the problem must be elaborately organized and conducted. The organization and conduct of such an investigation falls outside of the purposes of this Committee's investigations.

101.49 Conclusions to be Drawn from a Study of the Literature Relating to Smoke Abatement in Large Cities: Smoke abatement in large cities has been a matter of public interest for many years and the literature on the subject is extensive. It presents evidences of wide differences in the practice of cities in their efforts to secure relief from smoke, and many points of disagreement in the opinions of experts as to the effects produced by smoke. This condition emphasizes the fact that the art of smoke abatement has not as yet been fully developed, and that much in the nature of scientific research and investigation remains to be accomplished before definite standards of practice can be established.

The more important facts and conclusions which seem to be generally accepted, or which are justified by the weight of the evidence presented, have been set forth in the concluding paragraphs of each section of this review. These may be summarized as follows:

1. Definite evidences of interest in smoke abatement date back six centuries or more to the time of Edward I (1272–1307) in England. The first authentic information relating to the use of coal is contained in complaints against it as a nuisance.

2. The British Parliament, in 1819, appointed a Select Committee to study and report upon the matter of smoke abatement. Since that date, there have been innumerable discussions and reports of investigations and the mass of literature has grown with great rapidity.

3. Two conceptions of the meaning of the word "smoke" exist. The usual and popular conception regards smoke as the visible exhalation of a burning substance. The other conception takes account of all the products of combustion, both visible and invisible, solid and gaseous.

4. Smoke becomes an object of concern to the city smoke inspector immediately upon being discharged from the stack. It is assumed to be objectionable in direct proportion to its visible density. The controlling factors in smoke inspection are:

a. The requirements laid down by the ordinance, under which action proceeds, as to the character of non-permissible smoke, as, for instance, "dense smoke" or "black smoke."

b. A standard by which smoke discharges may be evaluated in terms to meet the requirements of the ordinance.

c. The means by which smoke observations may be made and recorded.

5. A survey of the atmosphere of several of the world's great cities shows an improvement in atmospheric conditions during recent years. It shows also that Chicago suffers less from the effects of smoke than certain other large cities of this and other countries.

6. The comparison of the air of cities with that of the country has revealed characteristics which may and apparently must be attributed to the smoke of the cities; but it has also been shown that they may in part be attributed to other sources, as, for example, leakage from gas mains, the pollution due to sewers, the dust of the streets and decaying organisms. Air analysts have admittedly not been able to separate the products of combustion as dispersed in the air from other agents of air pollution.

7. The industrial activity of all important cities has brought about an increase in coal consumption which is greater than the increase in population. Smoke formation and the consequent pollution of the atmosphere by smoke have in recent years tended to increase, and have done so except so far

as the adoption of various means in smoke prevention have proved effective. The fact is repeatedly pointed out that, in securing results of scientific value for use in abating smoke, no one individual and no one city can accomplish the work that must be done. The observations must be numerous and must extend over decades.

8. The fact appears firmly established that there is a well defined relation between smoke and fog and that the presence of smoke induces fog. It is agreed that sunshine is a function of the amount of smoke present in the atmosphere.

9. Certain investigations have shown that the amount of carbon dioxid in the atmosphere of cities is, as a rule, only about one per cent greater than that in country air. The sulphur compounds in city air usually form a more important constituent than is the case in country air. Sulphur compounds in the atmosphere are generally due to the combustion of coal.

10. Among the sources of pollution of city air by smoke, the world over, domestic chimneys are conspicuous. The mention of them by observers and students is much more frequent than the mention of any other source.

11. The most successful means which have been employed to abate smoke have included not only legal prohibition but also the development of co-operative and educative measures.

12. The mechanical and physical means in smoke abatement which are suggested in the literature on the subject, not all of which can be accepted as practicable, include:

a. The removal of fuel consuming industries to points remote from the city.

b. The construction of smoke sewers or community chimneys of such size and height as to permit of directing the discharges of many flues into one stack and thereby delivering the combined stream far above the city.

c. The establishment of central heating and power plants.

d. The employment of devices for washing smoke discharges before their emission into the atmosphere.

e. The condensation and deposition of smoke particles by means of electric devices.

f. The abolition of many small coal fires through an extension of the use of gas and electricity.

g. Improvement in methods of firing.

13. Fires of bituminous coal may be maintained without becoming sources of visible smoke, providing certain principles are recognized in the design of furnaces and in the manner in which they are fired.

14. It is possible to secure smokeless combustion of fuel in fires under stationary boilers by hand-firing, though such a result implies careful supervision.

15. Most mechanical stokers and methods of stoking which serve to distil and consume the volatile products contained in the fuel are generally approved as a means in smoke abatement where bituminous or other coals high in volatile matter are used.

16. With reference to the effects of smoke, the following conclusions seem justified by the literature on the subject:

a. There is a general agreement among sanitary authorities that polluted air is harmful to health, but at the present time there exists no accurate method of measuring this harm nor of determining the relative responsibility of the different elements which enter into the mixture of gases and solids commonly referred to as atmospheric air.

b. The direct effects of smoke or of any of its attributes, including soot, dust and gases, in amounts which may ordinarily pervade the atmosphere of a smoky city are not shown to be detrimental to persons in normal health, but the general physical tone is lowered as the result of long continued breathing of polluted air.

c. The direct effect of smoke upon those who are ill has been most extensively studied in connection with tuberculosis and pneumonia. It appears that smoke does not in any way stimulate the onset of the tubercular process nor militate against the rapidity of recovery when once this disease has been contracted, but that it has a direct antiseptic effect and tends to localize the disorder. In cases of pneumonia, the effect becomes seriously detrimental.

d. The tarry matter and sulphur compounds present in coal smoke have been shown by experiments to affect certain classes of vegetation when applied in sufficient quantities.

e. Smoke is popularly regarded as a source of loss and damage in its effects upon building materials, objects of virtu, clothing and other property. While these effects of smoke seem obvious, it has not been possible to estimate their extent with any degree of accuracy.

102. SMOKE ABATEMENT IN CHICAGO

SYNOPSIS: Public interest in smoke abatement has been active in Chicago for a period of 40 years or more. It has been discussed by newspapers, by various associations and by many public speakers. The city government first took official cognizance of it in 1881, when the first smoke abatement ordinance was passed. Since that date, there have been three other smoke abatement ordinances. Under these ordinances Chicago has developed a well organized department of smoke inspection.

102.01 Public Interest in Smoke Abatement: Smoke abatement in Chicago has been a subject of public interest for more than 40 years. This interest has found expression in newspaper discussions, in public addresses, in the action of unofficial or voluntary societies and associations, and in the enactment of various ordinances by the City Council. In 1874, and for a number of years thereafter, the work of smoke abatement was stimulated by the "Citizens Association," a voluntary organization having for its object the promotion of public welfare. This association appears to have concerned itself chiefly with the legal and legislative aspects of the problem. After the first smoke abatement ordinance was enacted, it assisted in the prosecution of violators, and insisted that those in charge of public buildings, office buildings, schools, pumping stations and other public institutions should not offend the law. It cordially supported recommendations made by the Mayor in 1905 regarding modifications in the methods of enforcement of the smoke abatement ordinance, and it conducted two or three investigations which exerted an influence upon the subsequent enactment and enforcement of legislation.

In the early days, there was much discussion concerning the practicability of abating smoke and the right of the city to require its abatement. Differences of opinion arose as to the procedure best calculated to bring about the desired results.

In 1891, "The Society for the Prevention of Smoke" was organized through the patronage of a number of public spirited citizens. This society, with several other voluntary organizations formed at this time, had for its main purpose the physical betterment of the city preparatory to the World's Fair of 1893. The officers and directors were business men of Chicago and the staff included engineers and experts. The methods adopted were educative and co-operative. The work was vigorously pushed and the large expense involved was borne by private subscription. The daily papers gave it their constant and consistent support. Inspections and tests were made of plants which violated the smoke ordinance, and reports containing suggestions for changes in equipment, fuel or methods of operation were submitted to the owners. The effort was to show that no pecuniary loss need be involved in the abatement of smoke, nor in the use of smoke abating appliances. Particular attention was paid to smoke from steam locomotives and the use of several smoke abating devices was inaugurated. The activities of the society ceased in 1893, its work having been, in a measure, accomplished.

More recently, numerous organizations have interested themselves in the general problem of smoke abatement, but have accomplished little except in so far as they have stimulated interest in the subject. Few new facts have been developed but, in response perhaps to these manifestations of public interest, a gradually developing train of municipal legislation has appeared, a brief review of which is important in this connection.

102.02 The Ordinance of 1881: Chicago's first smoke ordinance went into effect in April, 1881. It declared the emission of "dense smoke" a public nuisance; it applied to all classes of service except private residences; it held not only the owners of plants, but also persons employed in operating them, responsible for the violations; and it fixed a fine of not less than $5.00 nor more than $50.00 as a penalty for each violation. The ordinance was regarded as a health measure, and its enforcement was made the joint duty of the Commissioner of Health and the Superintendent of Police. The ordinance in full is as follows:

> ORDINANCE OF 1881
>
> Section 1650. The emission of dense smoke from the smoke-stack of any boat or locomotive or from any chimney, anywhere within the City, shall be deemed and is hereby declared to be a public nuisance; provided that the chimneys of buildings used exclusively for private residences shall not be deemed within the provisions of this ordinance.
>
> Section 1651. The owner or owners of any boat or locomotive engine and the person or persons employed as engineer or otherwise in the working of the engine or engines in said boat or in operating such locomotive, and the proprietor, lessee or occupant of any building, who shall permit or allow dense smoke to issue or be emitted from the smoke-stack of any such boat or locomotive, or the chimney of any building within the corporate limits, shall be deemed and held guilty of creating a nuisance, and shall for every such offense be fined in a sum not less than Five Dollars nor more than Fifty Dollars. Sections 1650, 1651 and 1652 shall take effect and be in force from and after May 1, 1881.
>
> Section 1652. It shall be the duty of the Commissioner of Health and the Superintendent of Police to cause Sections 1650 and 1651 of this Article to be enforced, and to make complaint and cause to be prosecuted all persons violating the same.

This ordinance was sustained by a strong public sentiment, which was aroused by the increasing quantities of smoke emitted in Chicago and by reports of activities in smoke abatement in other cities, but the means which could be made available to secure the enforcement of the ordinance were limited. No standards of density were recognized. Many of the larger coal users did not believe it possible to prevent smoke. Besides these difficulties, the enforcement of the ordinance was made incidental to the administration of two departments charged with other large responsibilities, and yet for three years following its passage there was considerable activity under it. During the period from 1881 to 1884 approximately 4,000 formal visits of inspection were made, 2,000 warning notices were sent out and a number of suits were filed and fines imposed. After 1885, activities under the ordinance gradually decreased, in consequence no doubt of the opposition of coal consumers and of the imperfect character of the ordinance itself. During the year 1889 only seven suits were filed. With the approach of the World's Columbian Exposition in 1893, a revival of interest in smoke abatement manifested itself, and during the Exposition many efforts were put forth to reduce the smoke of Chicago. By resolution of the Council, individual offenders were called to account for permitting the emission of smoke from their stacks; means whereby the ordinance might be made more effective were discussed in the Council, committees were appointed to investigate and report, and resolutions bearing upon many different aspects of the general question of smoke abatement were passed. But with the business depression which followed the Exposition, agitation of the subject gradually subsided.

In the early years of the present century, smoke abatement again became an active public issue, and, as a result of agitation and discussion, a new and a better ordinance was proposed. At a meeting of the Council in 1902, the Committee on Judiciary recommended the adoption of an ordinance creating a Department for the Inspection of Steam Boilers and Steam Plants. This was in line with a suggestion made by the smoke inspector in his report for 1894. On March 23, 1903, the new ordinance was passed.

102.03 The Ordinance of 1903: This ordinance, creating a Department for the Inspection of Steam Boilers and Steam Plants, provided for a Board of Inspectors, consisting of a Chief Inspector of Steam Boilers and Steam Plants, a Supervising Mechanical Engineer and Deputy Inspector of Steam Boilers and Steam Plants, and a Chief Smoke Inspector. It declared the emission of dense smoke from smoke-stacks or chimneys, including those of boats or locomotives, a nuisance. It fixed the permissible duration of emissions at three minutes in any hour, except in cases of cleaning out a fire-box or building new fires, when six minutes were allowed. It made the penalty for violations of the ordinance not less than $10.00 nor more than $100.00; no prosecutions were to be begun unless, within ten days prior thereto, at least three notices should have been mailed to the offender advising him that dense smoke had been seen issuing from his premises. The ordinance provided also that no new steam plants should be constructed nor old ones reconstructed until plans and specifications had been filed with and approved by the Board of Inspectors; nor should new plants or reconstructed plants be used without a certificate from the Board authorizing such use. A fee was required for the inspections and a penalty fixed for the violation of either of these specific provisions. Private residences (not including flat or apartment buildings with more than three apartments) were exempted from inspection. The ordinance further sought to protect the public by providing that a fine of $100.00 be imposed for the making of excess charges by inspectors or for the issuing of certificates without actually making inspections, and that the action of the offender be reported to the Board of Civil Service Commissioners. The ordinance, so far as it relates to smoke, is as follows:

ORDINANCE OF 1903

An Ordinance
Creating a Department for the Inspection
of Steam Boilers and Steam Plants
Passed March 23, 1903
(Sections relating to Smoke)

Section 7—*Chief Smoke Inspector:* There shall be a Chief Smoke Inspector, who shall be appointed by the Chief Inspector of Steam Boilers and Steam Plants from an eligible list prepared in accordance with the Civil Service Act and the rules of the Civil Service Commission.

Said Chief Smoke Inspector, before entering upon the duties of his office, shall execute a bond to the City of Chicago in the sum of five thousand dollars ($5,000.00), with two or more sureties to be approved by the Comptroller, conditioned for the faithful performance of the duties of his office.

Section 8—*Board of Inspectors of Steam Boilers and Steam Plants:* The said Chief Inspector of Steam Boilers and Steam Plants, Supervising Mechanical Engineer and Deputy Inspector of Steam Boilers and Steam Plants, and Chief Smoke Inspector shall constitute the Board of Inspectors of Steam Boilers and Steam Plants.

Section 10. The emission of dense smoke from the smoke-stack of any boat or locomotive, or from any chimney anywhere within the City, shall be deemed and is hereby declared to be a public nuisance; but no prosecution for the emission of dense smoke shall be commenced, unless, within ten days prior thereto, at least three notices shall have been mailed to the offender that dense smoke has been seen emitted from his premises.

The owner, or owners, lessee, agent or manager of any boat or locomotive, and the proprietor, lessee or agent of any building, factory, mill, works or other establishment having smoke-stacks or chimneys, who shall permit or allow dense smoke to issue or to be emitted from the smoke-stack of any such boat or locomotive, or the chimney of any building, factory, mill, works, or other establishment having smoke-stacks or chimneys within the corporate limits, to exceed three minutes (excepting in cases where the fire-box is being cleaned out or new fire built therein, in which cases the limit shall be six minutes) in any hour of the day or night, shall be deemed and held guilty of creating a nuisance, and shall for every such offense be fined a sum not less than ten dollars ($10.00) nor more than one hundred dollars ($100.00).

It shall be the duty of the Board to see that the boiler or boilers, boiler setting, means of providing draft, smoke connections, and furnace or fire-box of each boiler inspected by it are of sufficient capacity and so constructed as with proper management to avoid the emission of dense smoke.

Prosecutions for all violations of this ordinance by persons allowing dense smoke to issue from any chimney shall be brought by the Chief Smoke Inspector, and the prosecutions for all other violations of this ordinance shall be brought by the Chief Inspector or Supervising Mechanical Engineer and Chief Deputy Inspector of Steam Boilers and Steam Plants in the name of the City of Chicago.

Provided, that no prosecutions under this ordinance shall be commenced against the owner, or owners, lessee, agent or manager of any boat, locomotive, or the proprietor, lessee or agent of any building, factory, mill, works, or other establishment having smoke-stacks or chimneys, the plant of which shall have been installed prior to the passage of this ordinance, until the expiration of one year after the passage of this ordinance, within which to rebuild and equip the same in accordance with the provisions of this ordinance: Provided, further, that no such owner, owners, lessee, agent or manager shall be entitled to said one year unless he shall at once commence his plans for the rebuilding and re-equipping of such plant and shall proceed with said work to the satisfaction of the Board upon inspection at intervals of three months during said period of one year.

Section 11—*Permits for New Plants:* From and after the passage of this ordinance, no new plants, nor any reconstruction of any old plants, for producing power and heat, or either of them, nor any new chimney connected with a steam plant, shall be erected or maintained in the City of Chicago until the plans and specifications of the same have been filed in the office of and approved by said Board, which plans and specifications shall show the amount of work and the amount of heating to be done by the said plant and all the appurtenances thereto, including provisions for the complete combustion of the fuel to be used and for the prevention of smoke, and a statement of the kind of fuel proposed to be used. Said plans and specifications shall also show that the room or apartment in which said plant shall be located is provided with doors, windows, air-shaft, fans and other means of ventilation sufficient to prevent the temperature of such room, apartment, basement or other portion of such building wherein said steam plant or apparatus is to be used from rising to a temperature higher than one hundred and twenty (120) degrees Fahrenheit, or that the atmosphere of any such apartment wherein such apparatus may be located may be entirely renewed every ten minutes. Upon approval of said plans and specifications, a duplicate set of which shall be left on file in said office, and the payment of fees as hereinafter provided, said Board shall issue a permit for the installation of said plant or said reconstruction. Said permit shall state the maximum amount of steam pressure to be carried. As soon as the board hereby created has examined the plans and specifications submitted for a new steam plant in a new building and has issued a permit for the installation of same, it shall notify the Commissioner of Buildings to see that the execution of the construction work on the building in which such plant is to be installed is carried out in conformity with the plans and specifications of the proposed steam plant for the execution of which a permit has been issued, with special reference to the amount of space to be used for such appurtenances, the size and construction of the chimney or chimneys to be used and the provisions for ventilation and proper temperature in the engine and boiler rooms. . . . [Remainder of section does not relate to the subject of smoke.]

Section 12—*Duty of Owners:* It shall be unlawful for any person to use any steam boiler or any tank or tanks subject to steam pressure until he shall have first procured a certificate from said Board that said apparatus may be safely used and that the boiler or boilers, boiler setting, means of producing draft, smoke connections, and furnaces or fire-box are of such size and capacity that they will do the work required, and be capable of being so managed for the purposes of generating steam that no dense smoke shall be emitted from the chimney connected with such furnace or fire-box; provided that Paragraph 1 of Section 12 shall not become effective until thirty days shall have elapsed after said owners shall have been notified by said Board that the said Board is ready to inspect their apparatus, and if it meets requirements of the ordinance to grant the certificate referred to.

If such owner, agent or person using a steam boiler or tank shall fail to notify said Board of his intention to make any alteration, repairs or enlargement of such steam plant and shall neglect to file plans and specifications for the enlargement or alteration of the same, and shall proceed to make such alterations, repairs or enlargement without permit therefor, he shall be liable to a fine of twenty-five dollars ($25.00) for each day on which he shall have prosecuted such alterations, repairs or enlargement without such permit and each day's violation shall constitute a separate offense. Provided, however, that minor necessary repairs which do not increase the capacity of said apparatus or involve any substantial alteration of structure may be made by or under the engineer in charge of such apparatus without permit or report thereof.

If at any time when inspecting a steam boiler, generator or other apparatus used for generating steam for power or heating purposes the Inspector of Boilers shall find that the furnace or fire-box in which fuel is used for the purpose of generating steam is so constructed or operated as to cause the emission of dense smoke from the chimney connected therewith, he shall report to said Board the condition of said plant. The owner of the steam boiler, generator or apparatus shall have the right to put in such appliance or make such alterations or use such fuel as in his judgment will prevent the emission of dense smoke, but this shall not constitute a compliance with this ordinance unless such appliance or such fuel shall actually prevent the emission of dense smoke. But said owner shall be entitled to receive this advice, cooperation and assistance of the Department for the Inspection of Steam Boilers and Steam Plants, and it shall be the duty of the officers of said department to make such further recommendations as will in its judgment prevent the emission of dense smoke.

Provided, however, that this ordinance shall not apply to boilers, generators or other apparatus used in private residences for generating steam solely for heating purposes; and for the purposes of this ordinance flat buildings or apartment buildings with more than three apartments shall not be classed as private residences, and any steam boiler, generator or other apparatus used for generating steam in flat buildings or apartment buildings having more than three flats or apartments shall be subject to inspection as hereinbefore provided.

Provided, also, that any boilers for heating purposes only, in which the permit specifies that not more than ten pounds of steam pressure to the square inch shall be carried, shall be known as "low pressure boilers."

After the next inspection of such boilers shall have been made following the adoption of this ordinance, inspections thereafter shall be made once every three years. That all of such low pressure plants may be inspected at any time thereafter, and without charges, with reference to the provisions for draft, complete combustion or degree of combustion of fuel and prevention of the emission of smoke.

Section 13—*Certificate Record:* When an inspection of a boiler or boilers, tank or tanks, jacket-kettle, generator or generators, superheater or superheaters, or any apparatus using steam under pressure has been made and the same shall be approved by the Chief Inspector or Supervising Mechanical Engineer and Chief Deputy Inspector of Steam Boilers and Steam Plants, he shall make and deliver to the person for whom the inspection was made, upon the payment of the fees hereinafter mentioned, a certificate of such inspection, which shall contain the date of inspection, together with a general description, for what purpose used, the number of try-cocks, steam and water gauges, the pounds pressure at which they may be safely used; which certificate shall be framed and put up in a conspicuous place in the engine or boiler room, and a record of the same shall be made and kept by said Board, in a well-formed book or books, indexed alphabetically or by locality. But such certificate shall not be a waiver of liability in case of any prosecution for the making of dense smoke.

Section 14—*Inspection of Repairs:* It shall be the duty of said Inspector, upon an application in writing made by any person, firm, corporation or agent, owning, leasing or controlling the use of any boiler, tank, jacket-kettle, generator or superheater, stating that the same is out of repair, or has been repaired, to examine the same when so repaired, and determine if such repairing has been properly done; and it shall be unlawful for any person, firm, corporation or agent to use any boiler, tank, jacket-kettle, generator, or superheater, after the same has been repaired, until a certificate shall have been procured from the Inspector to the effect that such repairing has been properly done and such boiler, tank, jacket-kettle, generator or superheater may be safely used, except as hereinbefore provided in Section 12 of the ordinance.

Section 15—*Fees:* The fees for inspection of steam boilers and other apparatus under this ordinance shall be as follows:

Class A—Including steam boilers, tanks, jacket-kettles, of a capacity of seventy-five gallons or over, generators or other apparatus using steam under pressure exceeding ten pounds per square inch in plants where only one such apparatus is used, five dollars each.

Class B—Steam boilers, generators or superheaters using steam under pressure exceeding ten pounds per square inch in plants where more than one such is used, five dollars for the first and three dollars for each additional apparatus.

Class C—Tanks and jacket-kettles, of a capacity of seventy-five gallons or over, using steam under pressure in plants where more than one such tank or jacket-kettle is used, one dollar each for all after the first.

Class D—All low pressure steam boilers as herein described in Section 12, three dollars each.

Class E—The fee for a permit for a new plant or for additions to an old plant shall be five dollars for each boiler installed.

All fees provided for in this ordinance shall be paid to the City Collector.

(Exemptions—Charitable, Religious and Educational Institutions not carried on for private gain or profit are exempted from payment of fees.)

Section 16—*Charging Excess Fees:* If any person shall take or receive any valuable thing from any person for the purpose of deceiving or defrauding any person or persons or for the purpose of favoring any person or persons, or if any inspector shall recommend the issue of any certificate of inspection without having at the time stated thoroughly examined and tested the boiler so certified, he shall be liable to a fine in the penal sum of one hundred dollars ($100.00) and his action shall be immediately reported by said Board to the Civil Service Commissioners.

Section 24—*Salaries:* The salary of the Chief Inspector of Steam Boilers and Steam Plants shall be $3,600.00 per annum, that of the Supervising Mechanical Engineer and Chief Deputy Inspector of Steam Boilers and Steam Plants $3,600.00 and that of Smoke Inspector of Steam Boilers and Steam Plants $2,000.00 per annum. There shall be appointed in addition to the above named officials, a Chief Clerk and such other assistants, inspectors and employes as the City Council may by ordinance prescribe and establish. It will be the duty of the Assistant Inspectors to report defects in furnaces and smoke-stacks as well as boilers and it shall be the special duty of the Deputy Smoke Inspectors to report dense smoke emitted from chimneys together with the probable causes therefor, determined by them on investigation of the plants connected with such chimneys.

Section 25—This ordinance shall take effect May 1, 1903. On that day the Inspector of Steam Boilers for the time being shall turn over to the Board hereby established all the books, accounts and property of the City of Chicago in his charge and possession and close up his accounts with the City Comptroller, and the Commissioner of Health shall transfer to the Board hereby created all the books and accounts of the Smoke Inspector.

This ordinance seems to have been unsatisfactory almost from the date of its passage, especially in its application to boats and to locomotives. It was claimed to be practically impossible for inspectors to observe moving boats and locomotives for the length of time specified in the ordinance and hence to secure evidence necessary to convict. As a consequence it soon gave way to a new law.

102.04 The Ordinance of 1905: A new ordinance was adopted in March, 1905. It retained the more important provisions of the previous law but forbade altogether the emission of dense smoke from boats or locomotives, while it allowed to other smoke producers an exemption of six minutes in any hour of the day or night. Further, only one notice within ten days prior to the beginning of the prosecution was required in the case of violations by boats or locomotives, while three such notices were required in the case of other violators. The forms of notices were specified. The ordinance so far as it relates to smoke is as follows:

ORDINANCE OF 1905

An Ordinance Relating to Steam Boilers, Steam Plants and Smoke passed March 20, 1905
Revised Municipal Code of Chicago
(Sections relating to Smoke)

(2210). Section 7—*Chief Smoke Inspector:* There shall be a Chief Smoke Inspector who shall be appointed by the Chief Inspector of Steam Boilers and Steam Plants according to law. Said Chief Smoke Inspector, before entering upon the duties of his office, shall execute a bond to the City in the sum of five thousand dollars with sureties to be approved by the Comptroller, conditioned for the faithful performance of the duties of his office.

(2211). Section 8—*Board of Inspectors of Steam Boilers and Steam Plants—to Inspect City and Board of Education Boilers:* The Chief Inspector of Steam Boilers and Steam Plants, the Supervising Mechanical Engineer and Deputy Inspector of Steam Boilers and Steam Plants and the Chief Smoke Inspector, shall constitute the Board of Inspectors of Steam Boilers and Steam Plants. The chief inspector of steam boilers and steam plants shall be chairman of said Board, and the supervising mechanical engineer and chief deputy inspector of steam boilers and steam plants shall be secretary of such board. (Any two members of the board shall constitute a quorum.) Said board shall have the same power over all steam boilers and steam plants owned or operated by the City, or the board of education, as over all other steam boilers and steam plants in the City; and all steam boilers and steam plants owned, operated, or controlled by the City or by the board of education of said City shall be subject to the requirements of their charter; and it shall be the duty of said board of inspectors of steam boilers and steam plants to inspect at least once in each year all of such steam boilers and steam plants as are owned, operated or controlled by the City, or by said board of education, and also to preserve a record of the condition of such steam boilers or steam plants by such inspection. No fee shall be charged or paid to said department nor to any employe under said department for the inspection of any steam boiler or steam plant or for the certificate of inspection issued by such department for any steam boiler or steam plant owned, operated or controlled by said City or said board of education.

(2212). Section 9. It shall be the duty of the board to inspect all boilers, tanks, jacket-kettles, generators or other apparatus used for generating or transmitting steam for power or using steam under pressure for heating or steaming purposes, and all other tanks, jacket-kettles and reservoirs under pressure of whatsoever kind except as hereinafter provided, as often as once in each and every year, etc. . . . It shall be the duty of the board to see that the boiler or boilers, boiler setting, means of providing draft, smoke connections and furnace or fire-box of each boiler inspected by it are of sufficient capacity and so constructed as with proper management to avoid the issuance or emission of dense smoke from any chimney or smoke-stack connected therewith.

(2213). Section 10—*Emission of Dense Smoke Prohibited—Nuisance—Abatement of Prosecution—Penalty:* The emission of dense smoke from the smoke-stack of any boat, vessel or locomotive, or from any chimney or smoke-stack of any building or premises in the City, shall be deemed and is hereby declared to be a nuisance and such nuisance may be summarily abated by the chief smoke inspector or any person duly authorized by him for that purpose. The remedy herein provided for abatement shall be cumulative to the remedies hereinafter provided for by prosecution and fine. Any person or corporation owning or operating any boat, vessel or locomotive, or any person in charge, possession or control of any boat, vessel or locomotive within the City who shall cause or permit dense smoke to issue or be emitted from the smoke-stack of any such boat, vessel or locomotive within the City at any time, shall be deemed guilty of a violation of this section and shall be fined not less than ten, nor more than one hundred dollars for each offense and each day on which any such person or corporation owning or operating any such boat, vessel or locomotive, or on which any person in charge, possession or control of any such boat, vessel, or locomotive shall cause or permit dense smoke to issue or to be emitted within the City from the smoke-stack of any such boat, vessel or locomotive, shall be deemed a separate and distinct offense. No prosecution for the emission of dense smoke from any such boat, vessel or locomotive shall be commenced unless within ten days prior to the institution of suit a notice in writing shall have been mailed to the person or corporation owning or operating the boat, vessel or locomotive from which dense smoke has been issued or emitted, or to the person in possession, charge or control of such boat, vessel or locomotive at the time such dense smoke was issued or emitted. In making proof of a violation of this section by any such person or corporation owning or operating any such boat, vessel or locomotive, or by any person in possession, charge or control of any such boat, vessel or locomotive, it shall not be necessary to prove the issuance or emission of dense smoke for any stated or specified period of time, but proof that at any time of day or night dense smoke has issued or been emitted from the smoke-stack of any such boat, vessel or locomotive within the City shall be deemed sufficient proof of violation of this section. Any person or corporation owning or operating, or any person in charge, possession or control of any building of any kind whatsoever in the City, whether used for trade, office or residence purposes or any other purpose whatever, who shall cause or permit dense smoke to issue or to be emitted from the chimney or smoke-stack of any such building within the City for more than six minutes, whether consecutive or not, within any hour at any time of day or night shall be deemed guilty of a violation of this section and shall be fined not less than ten or more than one hundred dollars for each offense. No prosecution for a violation of this section on account of the emission of dense smoke from the chimney or smoke-stack of any building within the City shall be begun against any person or corporation owning or operating such building or against any person in charge, possession or control of any such building, unless within ten days prior to the institution of suit at least three notices in writing, each notice relating to a separate and distinct offense, shall have been mailed either to the person or corporation owning or operating such building or to the person in possession, charge or control thereof.

(2214). Section 11—*Notices—By Whom Mailed—What to Contain:* The notices herein provided for shall be mailed by the chief smoke inspector, or by some person designated or authorized by him, and such notices shall be, in the case of notice sent on account of the emission of dense smoke from the smoke-stack of any boat, vessel, or locomotive, substantially as follows, to wit:—

To..........: You are hereby notified that on......day of ....A. D.......at or about the hour of.... o'clock....M, dense smoke was seen to issue from the smoke-stack (in case of a boat or vessel, setting out, if known, the name or description of such boat or vessel, or in case of a locomotive, if known, the number and description thereof). You are hereby notified that prosecution for violation of section 2213 (i. e., above section 10) of the Revised Municipal Code of Chicago for 1905 will be commenced against you by the smoke inspector on account of such violation.

....
Smoke Inspector.

In case of the emission of dense smoke from the chimney or smoke-stack of any building, the notice shall be substantially as follows:

To..........: You are hereby notified that on the......day of....A. D.,......at or about the hour of....o'clock....M, dense smoke was seen to issue from the smoke-stack or chimney of the building or premises situated and known as Number........ (or such other description as will serve to identify such building). You are hereby notified that prosecution will be commenced against you by the smoke inspector for a violation against section 2213 of the Revised Code of Chicago of 1905.

....
Smoke Inspector.

Such notices sent on account of the emission of smoke from any building shall be numbered first, second and third, as the case may be.

(2215). Section 12. Prosecution for all violations of this chapter against persons causing or permitting dense smoke to issue or be emitted from any smoke-stack or chimney, shall be instituted by the chief smoke inspector. Prosecutions for all other violations of this chapter against any person or corporation, shall be instituted by either the chief inspector of steam boilers and steam plants or the supervising mechanical engineer and chief deputy inspector of steam boilers and steam plants. All suits for the prosecution of any person or corporation for a violation of any of the provisions of this chapter shall be instituted in the name of the City of Chicago.

(2216). Section 13—*Permit for New Plants—Plans, etc.:* No new plants, nor any reconstruction of any old plants for producing power and heat, or either of them, nor any chimney connected with a steam plant, shall be erected and maintained in the City until the plans and specifications of the same have been filed in the office of and approved by the board of inspectors of steam boilers and steam plants, which plans and specifications shall show the amount of work and the amount of heating to be done by such plant and all the appurtenances thereto, including provisions for the complete combustion of the fuel to be used for the prevention of smoke, and a statement of the kind of fuel proposed to be used. Such plans and specifications shall also show that the room or apartment in which such plant shall be located is provided with doors, windows, airshafts, fans and other means of ventilation sufficient to prevent the temperature of such room, apartment, basement or other portion of such building wherein such steam plant or apparatus is to be used, from rising to a higher point than one hundred and twenty degrees

Fahrenheit, or that the atmosphere of any such apartment wherein such apparatus may be located may be entirely renewed every ten minutes. Upon approval of such plans and specifications, a duplicate set of which shall be left on file in said office, and the payment of fine as hereinafter provided, said Board shall issue a permit for the installation of such plant or reconstruction. Such permit shall state the maximum amount of steam pressure to be carried. As soon as the board hereby created has examined the plans and specifications submitted for a new steam plant in a new building and has issued a permit for the installation of the same, it shall notify the commissioner of buildings to see that the execution of the construction work on the building in which such plant is to be installed is carried out in conformity with the plans and specifications of the proposed steam plant for the execution of which a permit has been issued, with special reference to the amount of space to be used for such appurtenances, the size and construction of the chimney or chimneys to be used, and the provision for ventilation and proper temperature in the engine and boiler rooms.

It shall be the duty of the supervising mechanical engineer and chief deputy inspector of steam boilers and steam plants to examine in detail all plans and specifications that may be submitted to the board, and to report upon the same for approval by the board. All permits shall be issued by an affirmative vote of the majority of the board.

(2217). Section 14—*Duty of Owners:* It shall be unlawful for any person to use any steam boiler or any tank or tanks subject to pressure other than city pressure until he shall first procure a certificate from said board that such apparatus may be safely used, and that the boiler or boilers, boiler setting, means of producing draft, smoke-connections, and furnace or fire-box are of such size and capacity that they will do the work required, and be capable of being so managed for the purpose of generating steam that no dense smoke shall be emitted from the chimney connected with such furnace or fire-box.

If such owner, agent or person using a steam boiler or tank shall fail to notify said board of his intention to make any alteration, repairs or enlargement of such steam plant, and shall fail to file plans and specifications for the enlargement or alterations of the same, and shall proceed to make such alteration, repairs or enlargement without a permit therefor, he shall be liable to a fine of twenty-five dollars for each day on which he shall have prosecuted such alteration, repairs or enlargement without said permit, and each day's violation shall constitute a separate offense. Provided, however, that minor necessary or emergency repairs which do not increase the capacity of such apparatus or involve any substantial alteration of structure may be made by or under the engineer in charge of such apparatus without permit or report thereof.

If at any time when inspecting a steam boiler, generator or other apparatus used for generating steam power for heating purposes, the inspector of boilers shall find that the furnace or fire-box in which fuel is used for the purpose of generating steam is so constructed or operated as to cause the emission of dense smoke from the chimney connected therewith he shall report to the board the condition of such plant. The owner of such steam boiler, generator or apparatus shall have the right to put in such appliance or make such alterations or use such fuel as in his judgment will prevent the emission of dense smoke but this shall not constitute a compliance with this chapter unless such appliance or such fuel shall actually prevent the emission of dense smoke.

Provided, that any boilers for heating purposes only, in which the permit specifies that not more than ten pounds of steam pressure to the square inch shall be carried, shall be known as "low pressure boilers."

After the next inspection of such low pressure boilers shall have been made following the adoption of this ordinance, inspections thereof shall be made once in every three years. But all of such low pressure plants may be inspected at any time thereafter, and without charge, with reference to the provisions for draft, complete combustion or degree of combustion of fuel and prevention of the emission of smoke.

(2218). Section 15—*Exception:* The provisions of this chapter relating to the inspection of boilers, generators or other apparatus carrying other than city pressure shall not apply to such boilers, generators or apparatus while in use or installed in any locomotive, steam or tug-boat. The provisions of this chapter relating to the inspection of steam boilers, generators or other apparatus carrying other than city pressure shall be held to apply to any steam plant such as steam boilers, generators or apparatus in use or installed in any steam roller, steam derrick, steam pile-driver, automobile or other movable structure or contrivance of any kind whatsoever used within the City.

(2220). Section 17—*Certificate of Inspection—Permit for New Plant, etc., Issuance or Possession not to Exempt from Prosecution for Emission of Dense Smoke:* The issuance or delivery by the board to any person or corporation of any certificate of inspection herein provided for, or the possession by any person or corporation of any such certificate shall not be held to exempt any person or corporation to whom such certificate was issued or delivered, or who is in possession or control of any such certificate, from prosecution for any violation of the provisions of this chapter in relation to or concerning the issuing or emission of dense smoke caused or permitted by any such person or corporation; the issuance or delivery by said board of any permit for construction of any new plant or the reconstruction of any chimney connected with any steam plant, shall not be held to exempt any person or corporation to whom any such permit has been issued or delivered or who is in possession of any such permit from prosecution on account of the emission or issuance of dense smoke caused or permitted by any such person or corporation.

(2221). Section 18—*Inspection of Repairs:* It shall be the duty of said inspector, upon application in writing made by any person or corporation owning, leasing or controlling the use of any boiler, tank, jacket-kettle, generator or superheater stating that the same is out of repair or has been repaired, to examine the same when so repaired and determine if such repairing has been properly done; and it shall be unlawful for any person or corporation to use any boiler, tank, jacket-kettle, generator or superheater, after the same has been repaired until a certificate shall have been procured from the inspector to the effect that such repairing has been properly done and such boiler, tank, jacket-kettle, generator, or superheater may be safely used, except as hereinbefore provided in this chapter.

(2222). Section 19—*Fees:* The fees for the inspection of steam boilers and other apparatus under this chapter shall be as follows:

Class A—Including steam boilers, tanks, jacket-kettles, of a capacity of seventy-five gallons or over, generators or other apparatus under a pressure exceeding ten pounds per square inch in plants where only one such apparatus is used, five dollars each.

Class B—Steam boilers, generators or superheaters under pressure exceeding ten pounds per square inch in plants where more than one such is used, five dollars for the first and three dollars for each additional apparatus.

Class C—Tanks and jacket-kettles, of a capacity of seventy-five gallons or over, under pressure in plants where more than one such tank or jacket-kettle is used, one dollar for each after the first.

Class D—All low pressure steam boilers as herein described in this chapter, three dollars each.

Class E—The fee for a permit for a new steam plant or for additions to an old plant shall be five dollars for each boiler or engine installed or for the addition or rebuilding of any smoke-stack or chimney or for any material alteration or changes made in such plant. The fees for the inspection of steam boilers and other apparatus above provided for shall be double the respective amounts above specified when an inspection is made on Sunday or any legal holiday at the request of the person or corporation owning or operating said steam boiler or other apparatus.

All fees provided for in this chapter shall be paid to the City Collector.

(2223). Section 20—*Exemptions—Charitable, Religious and Educational Institutions* not carried on or conducted for private profit or gain.

(2224). Section 21—*Charging Excess Fees:* If any person acting on behalf of the City under the provisions of this chapter shall take or receive any money or any valuable thing for the purpose of deceiving or defrauding any person or persons or if any inspector shall recommend the issue of any certificate of inspection without having at the time stated thoroughly examined and tested the boiler so certified, he shall be fined one hundred dollars for each offense.

(2231). Section 28 — *Apparatus — Records:* The city shall provide such instruments, books, papers and equipment as shall be necessary for the proper performance of the duties of such board, which shall be the property of said city and which shall be delivered by said board to its successor in office; said board shall report annually on or before the first day of February to the Mayor and City Council, and as often as required by said council, etc.

(2232). Section 29—*Report of Defects in Furnaces and Smoke-stacks:* It shall be the duty of the assistant inspectors to report to said board defects in furnaces and smoke-stacks as well as in boilers, and it shall be the special duty of the deputy smoke inspectors to report to said board dense smoke emitted from chimneys, together with the probable causes therefor, determined by them on investigation of the plants connected with such chimneys.

The Ordinance of 1905 proved unsatisfactory before the end of the year and was amended. In one of the Mayor's messages it was criticized on the ground that it discriminated against the owners of boats and of locomotives, and the City Law Department pronounced it invalid for three reasons, namely:

1. It allowed too great indulgence to smoke.
2. It imposed an unreasonable and unnecessary burden upon the city in requiring proof of time-length of smoke complained of and in the mailing of notices.
3. It restricted the initiation of all suits under the ordinance to the Smoke Inspector; whereas such duty belonged in part to the Health Commissioner.

This action, however, was not taken until substantial progress had been made in enforcing the ordinance.

102.05 The Ordinance of 1907: This ordinance represented a new phase in the history of smoke prevention in Chicago. The first ordinance imposed the matter of smoke prevention upon the City Health Department, and later ordinances made it a part of the work of the Department for the Inspection of Steam Boilers and Steam Plants. The Ordinance of 1907 created a new department of the City Administration, the "Department of Smoke Inspection." The head of this new department was given the title of Chief Smoke Inspector and the ordinance fixed his technical qualifications. Provision was also made for a Chief Assistant Smoke Inspector, whose qualifications were made the same as those of the Chief Smoke Inspector, and for deputy smoke inspectors, assistant smoke inspectors, clerks and stenographers. The ordinance is given in full as follows:

Ordinance of 1907

An Ordinance
Providing for Smoke Inspection and Abatement in the City of Chicago

Section 1. There is hereby established a department of smoke inspection, the head of which shall be known as the smoke inspector.

Section 2. The smoke inspector shall be appointed by the Mayor by and with the advice of the City Council.

Section 3. The person so appointed shall be a mechanical engineer, qualified by technical training and experience in the theory and practice of the construction and operation of steam boilers and furnaces and also in the theory and practice of smoke abatement and prevention.

Section 4. The smoke inspector, before entering upon the duties of his office, shall execute a bond to the city of Chicago in the sum of ten thousand dollars, with sureties to be approved by the Mayor, conditioned upon the faithful performance of the duties of his office.

Section 5. The salary of the smoke inspector shall be four thousand dollars ($4,000) per annum.

Section 6. There is hereby created the office of chief assistant smoke inspector, who shall be appointed by the smoke inspector as provided by law.

Section 7. The qualifications of the chief assistant smoke inspector shall be the same as the qualifications herein provided for the smoke inspector.

Section 8. The chief assistant smoke inspector shall, before entering upon the duties of his office, execute a bond to the city of Chicago in the sum of five thousand dollars ($5,000) with sureties to be approved by the Mayor, conditioned upon the faithful performance of the duties of his office.

Section 9. The salary of the chief assistant smoke inspector shall be three thousand dollars ($3,000) per annum.

Section 10. There shall be as many deputy smoke inspectors as shall be provided for by the City Council; their compensation shall be fixed by the City Council and they shall be appointed by the smoke inspector in the manner provided by law.

Section 11. There shall be as many assistant smoke inspectors as shall be provided by the City Council; their compensation shall be fixed by the City Council and they shall be appointed by the smoke inspector in the manner provided by law.

Section 12. There shall be as many clerks and stenographers assigned to this department as shall be provided by the City Council; their compensation shall be fixed by the City Council and they shall be appointed by the smoke inspector in the manner provided by law.

Section 13. The Mayor may in his discretion appoint a Smoke Abatement Commission composed of eight members, who shall act as advisors to the Mayor in the organization of the department and as advisors to the smoke inspector in the conduct of the department. The smoke inspector shall at all times receive, place, and keep on file in his office any suggestion, recommendation, advice or other communication which may be presented to him in writing by the Smoke Abatement Commission. The Smoke Abatement Commission may name an advisory board of mechanical engineers which shall consist of three consulting engineers of recognized ability and integrity, who have had experience in the installation and conduct of power and heating plants. This board shall act as advisors on engineering questions to the Smoke Abatement Commission and to the smoke inspector and to the members of the department. Meetings of the advisory board of mechanical engineers may be called at any time either by the Smoke Abatement Commission or by the smoke inspector. Members of the advisory board of mechanical engineers shall receive as their compensation the sum of ten dollars ($10.00) for each member for each regularly called meeting attended.

Section 14. No new plants or any reconstruction of any old plants for producing power and heat, or either of them or any new chimney connected with a steam plant shall be erected or maintained in the city until plans and specifications of the same have been filed in the office of and approved by the smoke inspector and a permit issued by him for such erection, reconstruction, or maintenance. Plans and specifications to be filed with the smoke inspector shall show the amount of work and the amount of heating to be done by such plant and all appurtenances thereto, including all provisions made for the purpose of securing complete combustion of the fuel to be used and for the purpose of preventing smoke; said plans and specifications shall also contain a statement of the kind of fuel proposed to be used, and said plans and specifications shall also show that the room or apartment in which such plant shall be located is provided with doors, windows, air shafts, fans, and other means of ventilation sufficient to prevent the temperature of such room, apartment, basement, or other portion of such building wherein such steam plant or apparatus is to be used, from rising to a point higher than 120 degrees Fahrenheit, and sufficient also to provide that the atmosphere of any such apartment, wherein such apparatus may be located, may be entirely renewed every ten minutes. Upon the approval of such plans and specifications, a duplicate set of which shall be left on file in said office, and upon the payment of the fees as hereinafter provided, the smoke inspector shall issue a permit for the reconstruction, erection, or maintenance of such plant. As soon as the smoke inspector has examined the plans and specifications submitted and has issued a permit as above provided, he shall then notify the Commissioner of Buildings to see that the execution of the work permitted is carried out in conformity with the plans and specifications, with special reference to the amount of space used, the size and construction of the chimney or chimneys used, the provisions for the prevention of smoke, and the provisions for ventilation, and for the proper temperature in the engine and boiler rooms.

Section 15. It shall be unlawful for any person to use any new or reconstructed plant for the production and generation of heat and power, or either of them until he shall have first procured a certificate from the smoke inspector that the plant is so constructed that it will do the work required and that it can be so managed that no dense smoke shall be emitted from the chimney connected with the furnace or fire-box.

Section 16. No owner shall alter or repair any chimney or any old furnace or device, which alteration, change or installation shall affect the method or efficiency of preventing smoke, without first submitting plans and specifications to the smoke inspector and securing a permit therefor, provided, however, that minor necessary or emergency repairs which do not increase the capacity of such plant or which do not involve any substantial alteration in structure and which do not involve any alteration in the method or efficiency of smoke prevention may be made by or under the engineer in charge of said plant without a permit. Any person who shall violate this section shall be liable to a fine of $25.00 for each day upon which he shall prosecute such alteration, change, or installation without a permit, and each day's violation shall constitute a separate offense.

Section 17. The emission of dense smoke within the city from the smoke-stack of any locomotive, steam boat, steam tug, steam roller, steam derrick, steam pile driver, tar kettle, or other similar machine or contrivance, or from the smoke-stack or chimney of any building or premises, excepting for a period of six minutes in any one hour during which the fire-box is being cleaned out or a new fire being built therein, is hereby declared to be a nuisance and may be summarily abated by the smoke inspector, or by any one whom he may duly authorize for such purpose. Such abatement may be in addition to the fine hereinafter provided. Any person or persons, or corporation, owning, operating, or in charge or control of any locomotive, steam boat, steam tug, steam roller, steam derrick, steam pile driver, tar kettle, or other similar machine or contrivance, or of any building or premises, who shall cause or permit the emission of dense smoke, within the city, from the smoke-stack or chimney of any such locomotive, steam boat, steam tug, steam roller, steam derrick, steam pile driver, tar kettle or other similar machine or contrivance, or from the smoke-stack or chimney of any building or premises so owned, controlled, or in charge of him, her, or them, except for a period of six minutes in any one hour during which the fire-box is being cleaned out or a new fire built therein, shall be deemed guilty of a violation of this ordinance, and upon conviction thereof shall be fined not less than ten dollars nor more than one hundred dollars for each offense; and each day of such emission of dense smoke shall constitute a separate offense.

Section 18. The fees for the inspection of plans and issuing of permits and for the inspection of plants and issuing of certificates shall be as follows:

For inspecting plans of new plants and plants about to be reconstructed, $2.00.

For inspecting plans for repairs and alterations, $1.00.

For examining a plant after its erection or reconstruction and before its operation and maintenance, $3.00.

The fee paid for the inspection or examination shall include the issuing of a permit or certificate, in case such permit or certificate is granted.

The smoke inspector may and he is hereby directed and instructed to remit all inspection or examination fees charged, or that hereafter may be charged, against any and all charitable, religious, or educational institutions when the furnace or other device or apparatus inspected is located in or upon premises used and occupied exclusively by such charitable, religious, or educational institutions; provided that such charitable, religious or educational institution is not conducted or carried on for private gain or profit; and provided further, that the smoke inspector may require every application for the remission of such fees to be verified by the affidavit of one or more tax payers of the city.

Section 19. Prosecutions for all violations of this ordinance shall be instituted by the smoke inspector and shall be prosecuted in the name of the City of Chicago.

The issuance and delivery by the smoke inspector of any permit or certificate for the construction or reconstruction, or any permit for the alteration or repair of any plant or chimney connected with a plant, shall not be held to exempt any person or corporation to whom any such permit has been issued or delivered, or who is in possession of any such permit, from prosecution on account of the emission or issuance of dense smoke caused or permitted by any such person or corporation.

Section 20. Any person who shall violate any of the provisions of this ordinance (except as is herein otherwise provided) shall be fined not less than $25.00 nor more than $100.00 for each offense.

Section 21. The city shall provide such instruments, books, papers and equipment as shall be necessary for the proper performance of the duties of the members of the department. The smoke inspector shall have charge of such instruments, books, papers and equipment, and shall deliver the same to his successor in office.

Section 22. The smoke inspector shall cause to be kept in his office a complete record of all plans submitted and of all permits issued and of all examinations of plants made by members of the department and also of all certificates issued.

Section 23. The smoke inspector shall make a report of the work of his department to the Mayor and City Council, annually, on or before the first day of February, and at other times as often as required by the City Council.

Section 24. If any person acting on behalf of the city under the provisions of this chapter shall take or receive any money or any valuable thing for the purpose of deceiving or defrauding any person or persons, or for the purpose of favoring any person or persons, or if any inspector shall recommend the issue of any certificate of inspection without having at the time stated thoroughly examined and tested the furnace, device or apparatus so certified, he shall be fined one hundred dollars for each offense.

Section 25. Chapter LXIV of the Revised Municipal Code of Chicago of 1905, as amended, so far only as said chapter refers to smoke inspection, is hereby repealed, and the position of chief smoke inspector created by said chapter is hereby abolished.

Section 26. This ordinance shall take effect on and after its passage and publication.

The ordinance was approved in July, 1907. It has since been amended to provide for a Chief Deputy Smoke Inspector. It has also been amended to provide for a revision of Section 17 to include dense smoke from open fires, as follows:

> "The emission of dense smoke within the city from the smoke-stack of any locomotive, steam boat, steam tug, steam roller, steam derrick, steam pile driver, tar kettle, or *any* other similar machine or contrivance, *or from any open bin, tank, vat, basin or other receptacle*."

102.06 Organization and Work of the Chicago Department of Smoke Inspection: The organization of the Chicago Department of Smoke Inspection consists of the Mayor, the Smoke Abatement Commission, the Advisory Board of Mechanical Engineers, the Smoke Inspector and his staff. The active staff of the Smoke Inspector in 1914 consisted of the following:

Smoke Inspector	1
Chief Deputy Smoke Inspector	1
Deputy Smoke Inspector in Charge	1
Mechanical Engineers	10
Deputy Smoke Inspectors (stack observers)	10
Clerks	2
Stenographers	2
Total	27

The appropriation for the work of the Department during the year 1914 amounted to $39,735.

The reports of the Department show that, owing to the magnitude of the work involved in covering the entire area of the city of Chicago with an effective system of smoke inspection, and owing also to the limited resources of the Department, the activities are now* largely confined to an area of "effective inspection" embracing 67 square miles or approximately 35 per cent of the area of the city. Within this area are located large power plants, many roundhouses and other facilities of the railroads, and a portion of the city's waterways. This area has been divided into 8 large divisions or districts each of which is subdivided into sections. There are 33 sections of such size that a single deputy smoke inspector may cover one section in a day. The area bounded by Chicago Avenue, Halsted Street, 22d Street and Lake Michigan, which embraces the central business district, is divided into 7 lettered sections, and the remaining territory within the area is divided into 26 numbered sections. These subdivisions of the area of effective inspection are shown by the map, fig. 7.

*September, 1914.

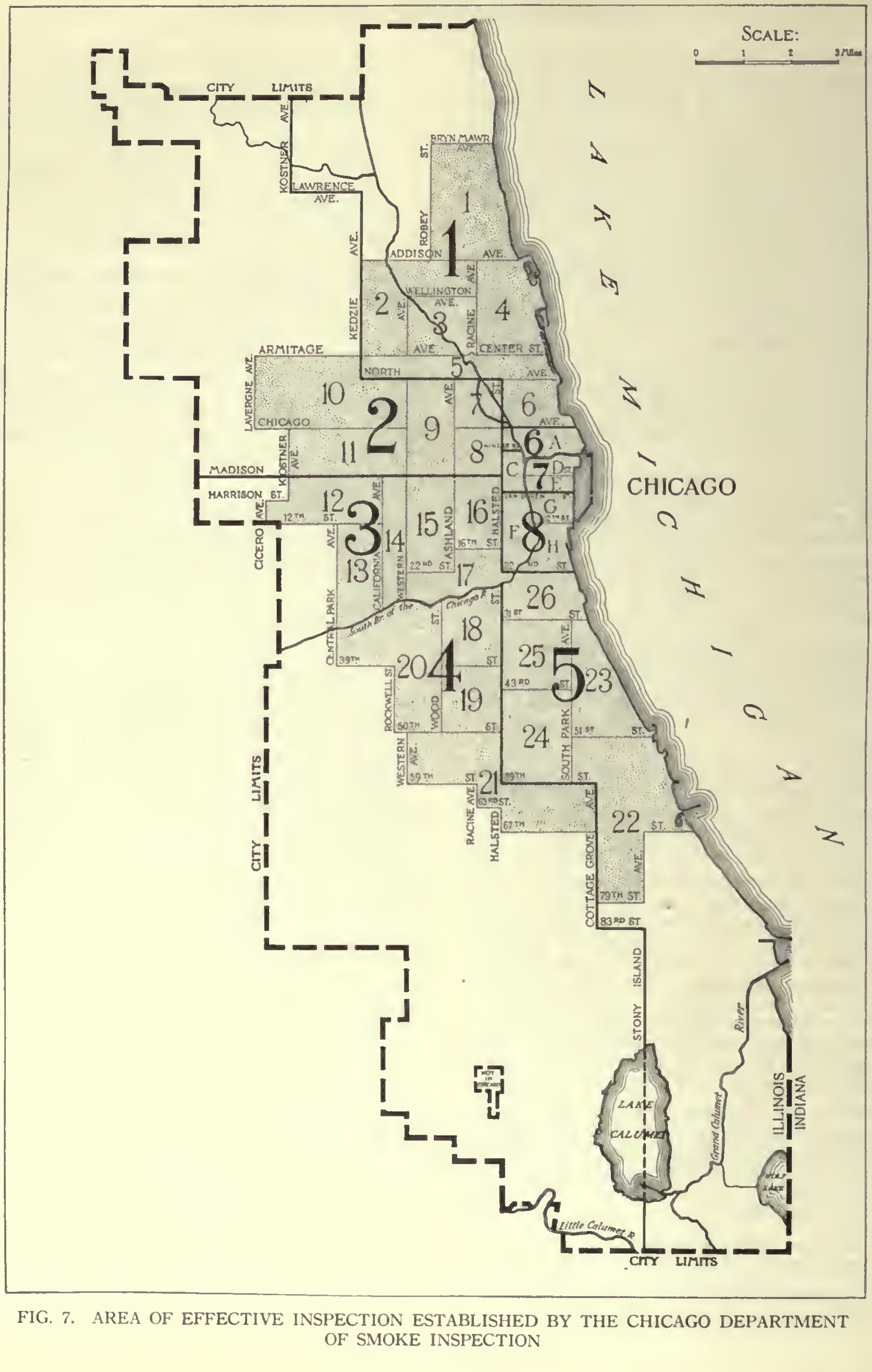

FIG. 7. AREA OF EFFECTIVE INSPECTION ESTABLISHED BY THE CHICAGO DEPARTMENT OF SMOKE INSPECTION

Each district is in charge of a mechanical engineer whose duties include supervision of the construction of new plants and other co-operative service to plant owners.

Smoke inspections are made daily, an observer or deputy inspector covering one section in a day.

In the administration of the Smoke Abatement Ordinance, the Department of Smoke Inspection has interpreted its responsibilities broadly. It has endeavored to co-operate with owners of fuel consuming plants by conducting an intelligent study of the problem. It has been reasonable in its requirements and has resorted to legal processes only when a lack of proper support has demanded recourse to the law. The work of the department has been based upon the Ringelmann Chart method of observation. The legal prohibition of the ordinance referring to "dense smoke" has been interpreted to mean No. 3, No. 4 or No. 5 smoke and, although no legal decision has been given on this point, the interpretation has been generally accepted. Emission of dense smoke for a period of six minutes during any hour when fires are being cleaned or new fires are being built is permitted in the case of stationary plants. Since a locomotive in service or a boat under way does not ordinarily clean its fire, the department has followed the practice of regarding the emission of dense smoke by a locomotive or boat for one minute or more a violation of the ordinance.

Stationary stacks and boats operate under what is known as the "thirty-day rule," by which two violations within a period of 30 days constitute sufficient cause for suit. When a report is received indicating a violation of the ordinance, a letter is sent to the owner or responsible party in charge of the plant in question warning him that a second violation within 30 days will result in suit. Should a second violation occur within the period specified, the evidence of both violations is sent to the prosecuting attorney and a letter is directed to the plant owner informing him of this action.

Formerly a letter was sent to the responsible party in charge of a plant which had violated the ordinance, inviting him to call at the office of the Smoke Inspector to explain the reason for the offense and to discuss methods of remedying the trouble if any should exist. This procedure was followed for five or six years before the more severe policy of filing suit upon the second violation within 30 days was put into general practice throughout the area of "effective inspection." This policy was adopted only after the Department had succeeded in obtaining proper co-operation from a large majority of the plant owners and had labored incessantly in its endeavor to secure the support of persistent offenders of the ordinance. The department reports, as a result of its experience in dealing with such offenders, that recourse to the law has seemed to offer the only satisfactory means of obtaining proper compliance with the provisions of the ordinance.

The method of inspection applied to railroad locomotives differs from that applied to stationary plants, in that the work is handled separately by a mechanical engineer who devotes all his time to this service. This engineer endeavors to co-operate with the railroads whenever possible, by instructing engineers and firemen in methods of operating which will secure a minimum amount of smoke. The Department reports that a definite policy of dealing with the railroads in the matter of violations of the smoke ordinance has been developed from data obtained during the past seven years, which serve to indicate the relative opportunity the Department has of observing violations on railroads, due to the following conditions:

1. The location of the railroads.
2. The number of locomotives operated by the railroads.
3. The opportunity of observing locomotive stacks as compared with the opportunity of observing the average stationary stack.

With consideration to these factors, a schedule has been developed which permits a varying number of violations per month for each railroad.

In an effort to co-operate with the Department of Smoke Inspection, the railroads have in many cases employed special smoke inspectors whose duties include the making of observations of smoke emissions by locomotives, the rendering of full reports of each observation to the motive power departments, the investigation of the city's complaints and the proper instruction of locomotive firemen. The railroads have in many cases adopted a strict practice of dealing with careless or indifferent employes by imposing penalties such as suspension or even dismissal from the service. The railroads now * employ

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* September, 1914.

38 regular smoke inspectors who devote all their time to the work, and 12 others who devote a major portion of their time to the work. These are organized as the Railroad Smoke Inspectors' Association of Chicago. This force greatly exceeds the entire number of employes in the city's Department of Smoke Inspection, and its maintenance has operated greatly in reducing the amount of smoke emitted by locomotives.

In the case of steamboats the method of inspection is similar to that employed for steam locomotives, with the exception that each steamer operates on the thirty-day-rule basis, in the same manner as do stationary stacks. The work is in charge of a mechanical engineer who cooperates, whenever possible, with owners and engineers by suggesting means and methods of abating smoke. The deputy inspectors or observers on the waterways report all smoke seen whether issuing from boats or from other sources.

102.07 Results Obtained in Smoke Abatement: As a result of the activities of the Department of Smoke Inspection there has been an unquestioned improvement in atmospheric conditions in Chicago. It is difficult to estimate the degree of this improvement but some measure of it may be shown by the reduction in the number of violations of the ordinance, which, for the year ending October 1, 1910, was about 30 per cent. In the reports of the Department of Smoke Inspection, the opinion is expressed that the improvement in conditions has been marked in all classes of service, and, in the case of steam locomotives, the report of February, 1911, states that the reduction in locomotive smoke "is probably in about the ratio of 41 per cent to 22 per cent." The statement is also made in this report that there is little hope of further material improvement with reference to locomotive smoke under the present conditions of steam operation. The experience of the Department of Smoke Inspection during the past three years, however, is stated to have shown that the smoke from locomotives can be reduced to a point not thought possible at the time the 1911 report was published. It is said that now it is not unusual for the locomotive smoke in the entire area of effective inspection to be as low as 6 or 7 per cent over periods of several weeks and it is believed that it will soon be easily possible to maintain this low percentage regularly.

Based upon the study and experience of the first four years of its existence, the Department of Smoke Inspection in the report of 1911 makes reference to the success of the methods employed, and recommends certain improvements and changes for the guidance of those who are interested in making further progress. Of first importance is considered the work of supervision of new plants. The policy of co-operation, which provides assistance and engineering advice to plant owners, is regarded as the most successful means of abating smoke.

Among recommendations made by the present* Chicago Department of Smoke Inspection are:

> 1. Adequate space should be provided for boilers and furnaces.
>
> 2. Plant owners and firemen should be given to understand that the requirements with regard to draft are by far the most important and that chimneys wherever possible should be not less than 100 feet high.
>
> 3. The use of automatic stokers is recommended for all plants having a boiler capacity above 200 horse-power and it is suggested that all classes of boilers be set higher than formerly in order to provide ample combustion space and to allow the installation of proper furnaces. Smoke devices, so-called, are not in themselves sufficient to meet the requirements of the Department.

Other recommendations are made with reference to improvements in office systems and details of work incident to the conduct of the Department.

102.08 Conclusions: It is evident from the facts presented in the preceding sections that public interest in the problem of smoke abatement is keen and active, and that the progress resulting from the Ordinance of 1907 and from the intelligent work of the Department of Smoke Inspection has been significant. The department has devised methods by which smokeless combustion of fuel may be had in both hand-fired and stoker-fired furnaces, and it has also shown that fires in stationary plants may be cleaned without emitting visible smoke. It has, however, concerned itself only with the practical questions of reducing visible smoke. It is apparent that the whole problem of smoke abatement, including that of suppressing the solid constituents of smoke, is one of great magnitude and that its scientific aspects have not as yet been dealt with by the city.

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* September, 1914.

103. THE TERRITORY EMBRACED BY THE COMMITTEE'S INVESTIGATION

SYNOPSIS: The Committee's Area of Investigation embraces a territory of 428 square miles. This area includes two zones, namely, Zone A, which is co-extensive with the city of Chicago, and Zone B, which comprehends an outlying area of 234 square miles completely surrounding the city except on the east, or lake side. Practically all the important yards, terminals and other railroad establishments of Chicago are located within the Area of Investigation.

103.01 The Area of Investigation: In entering upon a study of Chicago's atmosphere and of the sources of its pollution, it was early determined to give attention not merely to the area within the corporate limits of the city but also to a limited area of outlying territory. The activities of the city and of its suburbs intermingle and the interests of residents of city and suburb are in many respects common. Moreover, smoke in the atmosphere is extremely portable. When carried over the city from outside sources smoke is as effective in polluting the atmosphere as when arising from sources within the city itself. After careful consideration had been given the various manufacturing and transportation activities to be included, the Area of Investigation was defined as that which lies between Lake Michigan and the boundary indicated by a black line drawn on the official map of the Committee. The area is shown by fig. 8 in its relation to certain well known geographical features, and by fig. 9 in its relation to the location of railroads.

103.02 Characteristics of the Territory: The territory thus defined embraces all of the more important railroad yards in Chicago and its immediate vicinity. Its boundaries are practically identical with those of the "Chicago District" within which the several railroads concerned move cars and interchange traffic under a uniform code of rules. Its extent is as follows:

	SQ. MILES
In Illinois	386
In Indiana	42
Total	428

Within this territory 39 different railroad companies operate. Of this number, 25 maintain passenger and freight service and 23 are classed as trunk lines, while 14 perform transfer or switching service only. Of the trunk lines, 8 have no main tracks within the city limits but operate trains into the Chicago terminals over the tracks of other companies. Twelve railroads operate wholly within the Area of Investigation. A list of the 39 railroad companies follows:

Atchison, Topeka & Santa Fe Railway.
Baltimore & Ohio Railroad.
Baltimore & Ohio Chicago Terminal Railroad.
Calumet, Hammond & Southeastern Railroad.
Chesapeake & Ohio Railway of Indiana.
Chicago & Alton Railroad.
Chicago & Calumet River Railroad.
Chicago & Eastern Illinois Railroad.
Chicago & Erie Railroad.
Chicago & Illinois Western Railroad.
Chicago & North Western Railway.
Chicago & Western Indiana Railroad and the Belt Railway of Chicago.
Chicago, Burlington & Quincy Railroad.
Chicago Great Western Railroad.
Chicago, Indiana & Southern Railroad.
Chicago, Indianapolis & Louisville Railway.
Chicago Junction Railway.
Chicago, Milwaukee & St. Paul Railway.
Chicago River & Indiana Railroad.
Chicago, Rock Island & Pacific Railway.
Chicago Short Line Railway.
Chicago Union Transfer Railway.
Chicago, West Pullman & Southern Railroad.
Elgin, Joliet & Eastern Railway.
Grand Trunk Western Railway.
Illinois Central Railroad.
Illinois Northern Railway.
Indiana Harbor Belt Railroad.
Lake Shore & Michigan Southern Railway.
Manufacturers' Junction Railway.
Michigan Central Railroad.
Minneapolis, St. Paul & Sault Ste. Marie Railway.
New York, Chicago & St. Louis Railroad.
Pere Marquette Railroad.
Pittsburgh, Cincinnati, Chicago & St. Louis Railway.
Pittsburgh, Fort Wayne & Chicago Railway.
Pullman Railroad.
Wabash Railroad.

FIG. 8. THE COMMITTEE'S AREA OF INVESTIGATION

FIG. 9. THE COMMITTEE'S AREA OF INVESTIGATION, EMPHASIZING LOCATION OF RAILROADS

The location of railroad tracks within the Area of Investigation is indicated in fig. 9. When the city was small, railroad stations were established at convenient points and railroad yards were built in the suburbs. The city's growth in time enveloped these yards and the railroads, without relinquishing the facilities already possessed, built new and larger yards farther out, which in many cases also have been enveloped. In the working out of this process of expansion and envelopment, the more important railroads have developed a series of establishments along the line of their tracks, from the city terminus outward. These have taken the form of passenger and freight terminals, team yards, repair shops, locomotive engine houses, coach yards, receiving and sorting yards for freight, and freight interchange tracks. Establishments within the city have not been relinquished when new facilities farther out have been provided, because the added establishment has been necessary to meet the demands for increased service, and the possession of many points for the concentration and distribution of business within the city has contributed to the convenience of local communities as well as to the business advantage of the railroads. As a result the Area of Investigation is now intersected by numerous lines of railroad track and marked by the location of many yards and other centers of railroad activity. The extent of railroad tracks within the Area of Investigation is as follows:

	MILES
Main and other running tracks	1746
Yard and other side tracks	2144
Industrial tracks owned by railroad companies	390
Industrial tracks privately owned	222
Total	4502

Transportation activities include a considerable amount of water traffic within and about the Area of Investigation. The extent of waterways involved is as follows:

	MILES
Chicago River and its branches	15.3
Grand Calumet River	14.3
Little Calumet River	3.9
Drainage Canal	9.4
Ship canals in Indiana	5.4
Shore line of Lake Michigan	36.3
Total	84.6

As a matter of convenience in the presentation of facts, the territory embraced by the Committee's investigation as already described has been divided into two zones which will hereafter be referred to as "Zone A" and "Zone B," respectively (see fig. 8).

103.03 Zone A: This zone is co-extensive with the city of Chicago.* It is that area which, in figs. 8 and 9, is embraced by the broken line. It extends north and south a distance of 26 miles and its average width is approximately 8 miles. It touches on the north the corporate limits of Evanston and on the south the open prairies beyond Lake Calumet. Its eastern boundary is Lake Michigan and the Illinois-Indiana State Line. It presents 23.4 miles of shore line on Lake Michigan and includes an area of 194.4 square miles.† Its important characteristics in their relation to the problem of smoke abatement are significant. Its so-called "loop district," in which are centralized the city's financial and commercial activities, contains the lofty office buildings, the principal hotels, and the buildings of the City, County and National Governments. The city's manufacturing districts include the extensive establishments in South Chicago, Pullman, the Union Stock Yards and the Central Manufacturing District. Its industries engaged in the handling and storing of fuel, and of lumber and other building materials occupy large areas on both branches of the Chicago River. Its network of steam railroad tracks, its numerous and extensive railroad yards, and its shops and other terminal facilities for the care and handling of railroad equipment are well distributed over its area. Within the city are many beautiful parks and boulevards and extensive residential districts. These are some of the factors to be dealt with in a comprehensive study of the problem of atmospheric pollution.

The trackage of steam railroads in Zone A is as follows:

	MILES
Main and other running tracks	1005
Yard and other side tracks	1387
Industrial tracks	448
Total	2840

103.04 Zone B: This zone comprises the irregular belt of territory extending around the

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* The history of the city, the significance of its present activities, its rate of growth and the possibilities of its future development are presented in the Introduction to this report (sections 1.01 to 1.09, inclusive).

† This area includes the village of Morgan Park (3.1 square miles), the annexation of which to Chicago was held invalid by the State Supreme Court, June 21, 1912, more than a year after the Committee began its investigations. It has since been made a part of the city. It does not include a large number of parcels of "made" land, 1.7 square miles in extent, lying along the shore of Lake Michigan.

city of Chicago from the lake on the north to the lake on the south, represented in figs. 8 and 9 as the area between the boundary of the city and the heavy black line bounding the Area of Investigation. It presents 12.9 miles of shore line along Lake Michigan. It includes most of the city of Evanston, nearly two score suburban villages in Illinois, and the manufacturing cities of Hammond, Whiting and East Chicago in Indiana; it contains also extensive areas of unimproved land. It is traversed by all railroads entering the city and is occupied by many large railroad yards such as those at Godfrey, Proviso, Clearing and Dolton in Illinois, and those at Gibson and Kirk in Indiana. From the standpoint of railroad activity, Zone B is the hinterland of the city. Trunk and belt lines make it common ground upon which to interchange cars entering or leaving Chicago as well as those destined to points beyond. The extent of its activities may be judged by the fact that it contains 59 railroad yards and 1,662 miles of track, as follows:

	MILES
Main and other running tracks	741
Yard and other side tracks	757
Industrial tracks	164
Total	1,662

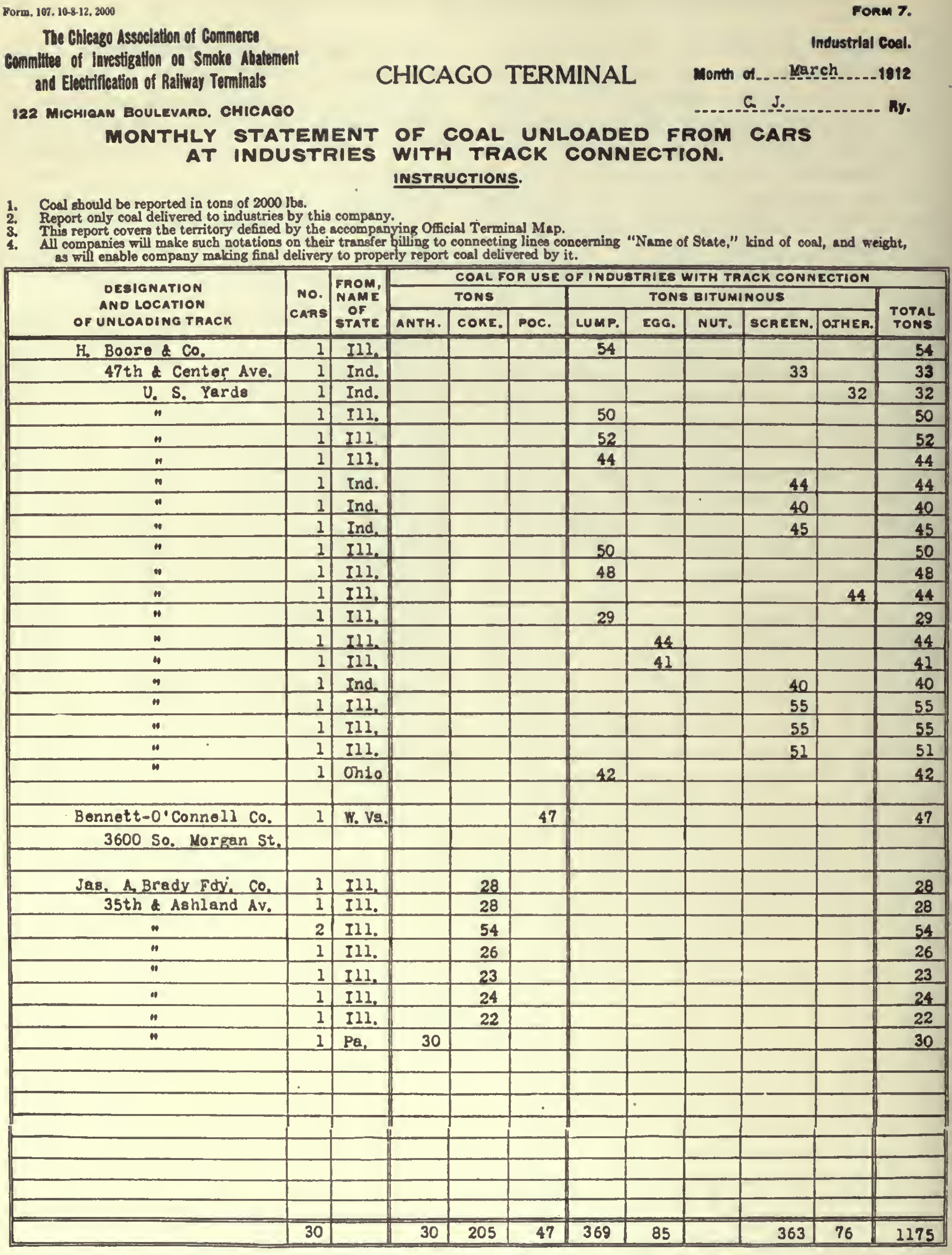
103.05 Summary of Statistical Facts: A summary of statistical facts relating to the Area of Investigation and to the extent of its railroad establishments and its waterways, of interest in their relation to the present study, is presented as table XXXIX.

TABLE XXXIX. SUMMARY OF GENERAL STATISTICS RELATING TO THE AREA OF INVESTIGATION

Item	Zone A	Zone B	Total Zones A & B
1	2	3	4
Area in square miles	194.4*	233.9	428.3
Population, U. S. Census 1910	2,185,283	194,869†	2,380,152†
Steam railroad track ... miles	2,840	1,662	4,502
Main and other running track ... "	1,005	741	1,746
Yard and other side track ... "	1,387	757	2,144
Industrial track owned by railroads ... "	285	105	390
Industrial track owned by industries "	163	59	222
Number of major yards	67	40	107
Number of minor yards	51	19	70
Business firms having private or individual industrial side tracks	1,615	386	2,001
Number of locations of industrial side tracks	1,989	495	2,484
Bridges over or carrying railroad tracks	1,853	546	2,399
Locomotive engine houses, number	46	19	65
Locomotive engine houses, capacity in locomotives	891	238	1,129
Locomotive coaling stations	51	22	73
Locomotive water stations	93	40	133
Locomotive ash-pits	65	19	84
Locomotive turn-tables	44	14	58
Water tanks	92	46	138
Interlocking plants	88	43	131
Interlocking towers	80	43	123
Automatic signals	879	316	1,195
Navigable waters ... miles	53.2	31.4	84.6
Shore line of Lake Michigan ... "	23.4	12.9	36.3
Chicago River and branches ... "	15.3	....	15.3
Drainage Canal ... "	3.7	5.7	9.4
Grand Calumet River ... "	8.9	5.4	14.3
Little Calumet River ... "	1.9	2.0	3.9
Ship canals in Indiana ... "	...	5.4	5.4

* Includes village of Morgan Park (3.1 square miles).

† Approximate.



Form. 107. 10-8-12. 2000

FORM 7.

The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals

122 MICHIGAN BOULEVARD, CHICAGO

CHICAGO TERMINAL

Industrial Coal.

Month of March **1912**

C. J. **Ry.**

MONTHLY STATEMENT OF COAL UNLOADED FROM CARS AT INDUSTRIES WITH TRACK CONNECTION.

INSTRUCTIONS.

1. Coal should be reported in tons of 2000 lbs.
2. Report only coal delivered to industries by this company.
3. This report covers the territory defined by the accompanying Official Terminal Map.
4. All companies will make such notations on their transfer billing to connecting lines concerning "Name of State," kind of coal, and weight, as will enable company making final delivery to properly report coal delivered by it.

DESIGNATION AND LOCATION OF UNLOADING TRACK	NO. CARS	FROM, NAME OF STATE	COAL FOR USE OF INDUSTRIES WITH TRACK CONNECTION								
			TONS			TONS BITUMINOUS					TOTAL TONS
			ANTH.	COKE.	POC.	LUMP.	EGG.	NUT.	SCREEN.	OTHER.	
H. Boore & Co.	1	Ill.				54					54
47th & Center Ave.	1	Ind.							33		33
U. S. Yards	1	Ind.								32	32
"	1	Ill.				50					50
"	1	Ill				52					52
"	1	Ill.				44					44
"	1	Ind.							44		44
"	1	Ind.							40		40
"	1	Ind.							45		45
"	1	Ill.				50					50
"	1	Ill.				48					48
"	1	Ill.								44	44
"	1	Ill.				29					29
"	1	Ill.					44				44
"	1	Ill.					41				41
"	1	Ind.							40		40
"	1	Ill.							55		55
"	1	Ill.							55		55
"	1	Ill.							51		51
"	1	Ohio				42					42
Bennett-O'Connell Co.	1	W. Va.			47						47
3600 So. Morgan St.											
Jas. A. Brady Fdy. Co.	1	Ill.		28							28
35th & Ashland Av.	1	Ill.		28							28
"	2	Ill.		54							54
"	1	Ill.		26							26
"	1	Ill.		23							23
"	1	Ill.		24							24
"	1	Ill.		22							22
"	1	Pa.	30								30
	30		30	205	47	369	85		363	76	1175

FIG. 10. TYPICAL RAILROAD REPORT OF DELIVERY OF REVENUE FUEL

104. COAL AND COKE CONSUMPTION*

SYNOPSIS: Smoke in the atmosphere has its origin in the combustion of fuel. This chapter presents the results of an investigation, made possible through the co-operation of many different agencies, showing the origin and quantities of coal and coke consumed by different fuel consuming services within defined subdivisions of the Area of Investigation. The methods employed are briefly described.

COAL AND COKE DELIVERED AND CONSUMED

104.01 Fuel Consumption and Atmospheric Pollution: Smoke, as a polluting agency in the atmosphere, has its origin in fuel. The amount of smoke arising from different classes of service is in each case a function of the quantity of fuel consumed. In recognition of this fact it was early determined to ascertain with as high a degree of accuracy as possible the total amount of coal and coke consumed within the Area of Investigation, the origin of the fuel, so far as this would aid in defining its character, and the various classes of service in which it was consumed. This has now, through the co-operation of many different agencies, been accomplished and statistical records have been made covering the calendar year 1912. Facts collected have been summarized and where possible checked against each other. The methods employed in the investigation and the results obtained are set forth in the sections which follow.

104.02 Coal and Coke Deliveries: All of the coal and coke consumed within the Area of Investigation is delivered either by rail or by water. The records for the year 1912 indicate that approximately 90 per cent is brought in by railroads and 10 per cent by vessels. That part of the solid fuel brought in by railroads and consigned to dealers and consumers is hereinafter referred to as "revenue fuel," in contradistinction from that brought in by railroads for their own use, which is hereinafter referred to as "company fuel" or "railroad fuel." Company fuel includes the coal and coke required for use in locomotives, in railroad heating and power plants and in shops. Obviously, there is a close relation between the coal delivered and the coal consumed during any given period. The two quantities, however, were not identical for the year 1912, and, in using statistics relating to deliveries as a basis for determining consumption, certain corrective factors have been introduced, the character and extent of which will be hereinafter discussed.

104.03 Coal and Coke Delivered by Rail as Revenue Freight: Throughout the year, the railroads made monthly reports on blanks furnished by the Committee, covering all coal and coke deliveries by rail. These reports gave information as to weights, names of consignees and points of delivery. Three different classes of delivery were recognized by these reports, a separate form being used for each class:

1. Form 7 provided for coal and coke unloaded from cars at industries having track connections.
2. Form 8 provided for coal and coke unloaded from cars at coal yards having track connections.
3. Form 9 provided for coal and coke unloaded from cars at team tracks.

Reports upon these three forms were returned each month, transmission usually being direct from the agent at the point of delivery to the office of the Committee. In the case of a few roads, reports from the several agents were sent first to the central office of the road and there reduced to a unit report which, when completed, was forwarded to the Committee. The process involved the return of more than 7,000 report sheets, covering the business of more than 200 separate railroad agencies. A typical report form, as filled out and returned by an agent, is presented as fig. 10.

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* A complete record of methods employed in the investigation here reported and of statistics compiled is preserved in the Archives of the Committee, Vols. L 1 and L 2.

Precaution was taken in the office of the Committee to avoid any inaccuracies in the returns received. Many of the reports were made the subject of individual inquiry for the purpose of verifying or correcting the quantities presented. All facts reported were re-tabulated and transferred to cards prepared for use in a system of automatic tabulation,* the machines of which are capable of sorting such cards and totaling values entered upon them, quickly and accurately. The process of making up statistical cards to give the desired information concerning the delivery by rail of revenue fuel for the year 1912 necessitated some 60,000 individual entries.

The results show that the railroads delivered during the year 1912 a total of 17,563,711 tons of revenue fuel to all classes of consumers within the Area of Investigation.

104.04 Coal and Coke Delivered by Boat as Revenue Freight: Through the courtesy of the United States Collector of Customs, Port of Chicago, and by permission granted by the Department of Commerce and Labor, the Committee obtained from the Collector's office a record of all cargoes of coal and coke delivered during 1912 at the ports of Chicago and South Chicago, together with the names of consignees. Through the information thus obtained, it was possible to trace the fuel delivered by boats directly to consumers or to dealers, and thence to the various classes of service in which it was consumed. Facts thus secured were combined to form monthly records covering each point of delivery or each important consignee, and were afterwards carried forward to statistical cards which permitted them to be re-grouped and summarized.

Coal placed in the bunkers of steam vessels at points outside the Area of Investigation, and consumed by the vessels themselves within the area, was made the subject of an independent investigation, the details of which are hereinafter presented.

The results show that, during the year 1912, boats delivered coal and coke totaling 1,706,556 tons to consumers and dealers within the Area of Investigation.

104.05 Coal and Coke Consumed by Steam Locomotives in Service: The methods to be employed in determining the quantity of fuel consumed by steam locomotives were made the subject of a number of conferences between the staff of the Committee and representatives of various railroads. As the result of facts brought forth at these meetings, it was decided that an accurate determination of the amounts of fuel consumed in this service must be based upon detailed reports from each of the several railroads. Blank forms for such reports and full instructions for their use were then prepared by the Committee for each class of locomotive service. The different locomotive services recognized were as follows:

1. Yard.
2. Road freight.
3. Freight transfer.
4. Passenger transfer.
5. Through passenger.
6. Suburban passenger.

The estimate of the coal consumed by locomotives was based upon the results of records kept during five observation periods† of a week each. These periods occurred in the months of January, March, May, August and October, each observation week beginning on the second Tuesday of the month and continuing day and night for seven days. All the fuel consumed by steam locomotives operating within the Area of Investigation was reported for each day during these weeks. The average daily consumption for all of the observation periods was taken as the basis for determining the total amount of fuel consumed during the year.

Although the Committee sought to secure uniformity in the process of making up the reports, the methods employed were not the same for all roads. The fuel consumed in the yard and transfer services was determined by most roads on a locomotive-hour basis, while that consumed in the road freight and passenger services was based on such units as the locomotive-mile, the ton-mile, the car-mile or the ton-hour, some roads employing one basis and some another. Several railroads conducted tests on locomotives in service in order to establish a basis from which

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* The Hollerith system of automatic tabulation was employed. For a more complete description of this system, see section 202.07.

† Other facts covered by the records kept during these periods, the influences governing the selection of periods, and the methods employed in reducing the information to a form suited to the Committee's requirements, are discussed in chapter 202.

to determine the consumption. Others based their reports upon statistical records of fuel consumption. Regardless, however, of the methods employed, the reports were sufficiently comprehensive to provide a basis for the elaborate distribution of quantities subsequently made by the Committee. All reports were carefully examined in the office of the Committee, and those which exhibited material variation from the average, or obvious discrepancies, were made the subject of prompt investigation for verification or correction.*

The reports gave the points between which or the location at which the movement requiring the fuel took place. For the purpose of aiding in apportioning the fuel to the districts in which it was consumed, all of the railroad lines were divided into sections of varying lengths which were called "route elements." The termini of these were fixed as points at which traffic ordinarily might vary in direction or amount, such as yards or junctions, or at which it crossed the boundaries of either Zone A or Zone B, and a route map was prepared on which the element termini were designated by circles and numbers. This map is presented as fig. 11.

TABLE XL. COAL CONSUMED BY STEAM LOCOMOTIVES IN SERVICE WITHIN THE AREA OF INVESTIGATION DURING 1912

Service	Zone A		Zone B		Zones A and B	
	Tons	Per Cent of Total	Tons	Per Cent of Total	Tons	Per Cent of Total
1	2	3	4	5	6	7
Yard	1,049,516	55.42	313,987	47.47	1,363,503	53.37
Road freight	136,115	7.19	122,672	18.55	258,787	10.13
Freight transfer	354,802	18.73	124,936	18.89	479,738	18.77
Passenger transfer	21,370	1.13	175	0.03	21,545	0.84
Through passenger	176,761	9.33	63,527	9.61	240,288	9.40
Suburban passenger	155,327	8.20	36,045	5.45	191,372	7.49
Totals	1,893,891	100.00	661,342	100.00	2,555,233	100.00

From the reports concerning train movements, involving a number of elements or locomotive movements within a yard or district, the fuel consumed in each element or in each yard was determined on a mileage or hourly basis. The individual records of consumption by yards and elements were carried forward to individual statistical cards, 1,400,000 of which were required for the entire record. By sorting these cards in automatic sorting machines and tabulating the data in automatic tabulating machines, the detailed information concerning distribution was obtained.

The results showing the amount of coal consumed by locomotives in service within the Area of Investigation during the year 1912 are presented in table XL.

104.06 Coal and Coke Consumed by Steam Locomotives at Locomotive Terminals: The amount of fuel consumed by steam locomotives at each locomotive terminal within the Area of Investigation was reported by the railroads monthly, throughout the year 1912, on forms provided by the Committee. These reports presented a complete record of the number of locomotives at the terminal each day, the class of service to which each locomotive belonged, the number of locomotive-hours spent and the amount of fuel consumed at the terminal. The methods employed by the roads in determining this fuel were essentially the same as those employed in determining the fuel consumed by locomotives in service. All reports were carefully examined and individual reports which showed material variation from the average were made the subject of investigation.

The results show that the total amount of fuel consumed by steam locomotives at locomotive terminals during 1912 was 260,167 tons.

104.07 Coal and Coke Consumed by Railroad Stationary Plants: It was found that 304 stationary plants for power, heating or other purposes were operated in the Area of Investigation by 39 railroads. Monthly reports setting forth the quantity of fuel consumed by each of these plants were furnished by the railroads, throughout the year 1912, on blank forms supplied by the Committee. The preparation of these reports presented few difficulties and they were found generally accurate and comprehensive, requiring little attention from the Committee for verification or correction.

The results show that, during the year 1912, the coal and coke consumed by railroad stationary plants amounted to 524,596 tons.

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* Typical reports covering fuel consumed by steam locomotives are presented as figs. 391 to 395, section 202.02.

OFFICIAL ROUTE MAP OF
CHICAGO
AND VICINITY
SHOWING RAILROAD LINES, TERMINALS,
YARDS AND JUNCTIONS
BY NAME AND NUMBER

NOTE: Each Railroad Route is indicated by a single line, each Yard and Junction Point by a circle and number, and the distances between same are indicated, to expedite the summation of traffic. Heavy line denotes Proprietary Company, light line denotes Tenant Company.

Office of Chief Engineer, Chicago November 1, 1912

FIG. 11. ROUTE MAP OF AREA OF INVESTIGATION, SHOWING RAILROAD LINES, TERMINALS, YARDS AND JUNCTIONS

104.08 Coal and Coke Delivered to Steam Vessels: The investigations of the Committee disclosed the fact that practically all of the fuel placed in the bunkers of steam vessels within the Area of Investigation was delivered to the vessels by dealers. The quantities of such fuel were ascertained through personal interviews with dealers and with agents or owners of the vessels, through whose co-operation a record was maintained throughout the entire year. This tonnage of bunker fuel was regarded as fuel withdrawn from the supply on hand within the Area of Investigation and was deducted from the total of fuel deliveries by rail and by water. The amount of coal actually consumed by steam vessels while operating within the Area of Investigation was determined by means described elsewhere (section 104.09).

The results show that the total amount of coal and coke placed in the bunkers of steam vessels within the Area of Investigation during the year 1912 was 126,556 tons.

104.09 Coal and Coke Consumed by Steam Vessels within the Area of Investigation: The amount of coal and coke consumed by steam vessels while operating within the Area of Investigation was determined from statistics and reports furnished by agents or owners of the vessels, and by tests conducted by the Committee similar to those employed by some of the roads in the determination of fuel consumed by locomotives. The data obtained covered the quantities and kinds of fuel consumed, the approximate time of each vessel in port, the points of docking and anchoring, and the time en route within the Area of Investigation. The navigable waterways were plotted and route elements established according to the method adopted for railroad lines. Each dock, harbor, intersection with zone limits, or other important point was indicated on the map of the waterways by a circle and a number, and the distances between such points were accurately determined. The waterway between any two adjacent points was termed a "water route element."

All of the data and statistics relating to consumption by steam vessels were entered upon blank forms prepared for the purpose and were subsequently re-tabulated and totaled. The vessels using the water routes were classified and the fuel consumption for each class was determined.

The results show that the amount of coal and coke consumed by steam vessels and other floating equipment within the Area of Investigation, during the year 1912, was as follows:

	TONS
Tugs and lighters	43,978
River barges, dredges, pile-drivers, etc.	11,739
Lake steamers and barges	36,651
Total	92,368

104.10 Coal and Coke Reshipped to Points within and Points outside of the Area of Investigation: The amounts of fuel reshipped from points within the Area of Investigation to points within and points outside the area were determined from information furnished the Committee by the railroads. In obtaining the data it was necessary to examine carefully the way-bills of the various railroad agents and to make frequent verification or correction of quantities. All fuel reshipped, regardless of its destination, was treated as fuel to be deducted from the supply within the area. If destined for points outside the Area of Investigation, its consumption could not affect the results of the Committee's investigation, whereas, if consigned to points within the area, its delivery constituted a reappearance of tonnage in the reports of deliveries.

The results show that, during the year 1912, the total amount of coal and coke reshipped to points within and points outside of the Area of Investigation was 800,413 tons.

104.11 Decrease in the Amount of Fuel in Storage: Changes in the amounts of coal and coke on hand or in storage at various points on December 31, 1912, as compared with amounts on hand on January 1, 1912, were ascertained from each dealer, and from each consumer whose supply might vary materially. Circular letters requesting the necessary information, accompanied by suitable blank forms, were sent to all dealers within the area and many personal calls were made. Personal calls were also made on all railroad agents for the purpose of obtaining the names of industries and coal yards at which more than 500 tons of fuel had been kept in storage at any time during 1912. The increase or decrease in the railroad fuel in storage was disregarded, since reports showed that no fuel was taken from railroad storage for distribution to other classes of service unless reported in the usual way as fuel delivered. The increase or decrease in the amount of coke in a large storage yard at Stockton, Ind., which is within the limits of Zone B, was not considered and the deliveries to this storage were not reported by the railroads. The coke taken from this storage, however, for delivery to dealers and consumers, was reported in the deliveries by rail or by water, and was therefore accounted for in determining the total consumption within the Area of Investigation. Other similar but smaller storages were considered individually as factors affecting the total increase or decrease of fuel in storage.

The results show that, during the year 1912, the supply of fuel on hand and in storage within the Area of Investigation decreased by a total of 231,041 tons.

104.12 Coal Equivalent of the Fuel and By-Products Manufactured by the Gas and Coke Plants within the Area of Investigation: The amounts of coal and coke delivered during the year to plants engaged in the manufacture of gas, coke and by-products within the Area of Investigation were determined from the reports of deliveries by rail or by water and were included in the totals of such deliveries. Not all such fuel, however, was consumed in these manufacturing processes, a large part being converted into gas, coke and by-products. The quantities thus converted were determined from statistical information reported by officials of the plants, and this tonnage was deducted from the quantities delivered to disclose the net amount of fuel consumed in this service.

The results show that, during the year 1912, the total amount of the coal equivalent of the fuel and by-products produced within the Area of Investigation was 797,817 tons.

104.13 Summary of the Fuel Consumed within the Area of Investigation: By combining the values set forth in the preceding sections (104.03 to 104.12 inclusive), the total consumption of coal and coke within the Area of Investigation during the year 1912 may be shown. The result of such a combination is presented in table XLI, in which are shown amounts of fuel delivered, amount consumed by railroads and amounts involved in the various factors of adjustment applied to the quantities delivered to obtain the net quantity consumed.

TABLE XLI. SUMMARY OF THE COAL AND COKE CONSUMED WITHIN THE AREA OF INVESTIGATION

Item	Tons	Total
Coal and coke delivered by rail as revenue freight (sec. 104.03)	17,563,711	
Coal and coke delivered by boat as revenue freight (sec. 104.04)	1,706,556	
		19,270,267
Coal and coke consumed by steam locomotives in service (sec. 104.05)	2,555,233	
Coal and coke consumed by steam locomotives at locomotive terminals (sec. 104.06)	260,167	
		2,815,400
Coal and coke consumed by railroad stationary plants (sec. 104.07)		524,596
Coal and coke consumed by steam vessels within the Area of Investigation (sec. 104.09)		92,368
Decrease in amount of fuel in storage (sec. 104.11)		231,041
		22,933,672
Deductions:		
Coal and coke delivered to steam vessels but not consumed within the Area of Investigation (sec. 104.08)	126,556	
Coal and coke reshipped from points within the area to points within and points outside the area (sec. 104.10)	800,413	
Coal equivalent of the fuel and by-products produced by gas and coke plants (sec. 104.12)	797,817	
		1,724,786
Net total	....	21,208,886

THE ORIGIN OF FUEL CONSUMED

104.14 Sources of Fuel: The various reports of fuel delivered and consumed included a description of the fuel or a statement of its origin. All fuel reported was classified as anthracite, Pocahontas,* coke or bituminous coal. The following shows the amount of fuel of each class consumed within the Area of Investigation during the year 1912:

KIND OF FUEL	ORIGIN	TONS	PER CENT OF TOTAL
Anthracite	Pennsylvania	1,827,158	8.62
Pocahontas	West Virginia	1,230,787	5.80
Coke	Various States	3,435,753	16.20
Bituminous	Illinois	9,184,126	43.31
Bituminous	Indiana	3,084,688	14.54
Bituminous	Other States	2,446,374	11.53
Totals		21,208,886	100.00

The consumption of the different kinds of fuel by zones is as follows:

KIND OF FUEL	ZONE A TONS	ZONE B TONS	ZONES A AND B TONS	PER CENT OF TOTAL
Anthracite	1,633,002	194,156	1,827,158	8.62
Pocahontas	1,174,742	56,045	1,230,787	5.80
Coke	3,099,302	336,451	3,435,753	16.20
Bituminous (all sources)	11,675,477	3,039,711	14,715,188	69.38
Totals	17,582,523	3,626,363	21,208,886	100.00

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* It has not been possible to determine the degree of accuracy attending the use of the term "Pocahontas" in the reports received through different agencies. It is probable that as here used it applies to any semi-bituminous coal from the West Virginia region.

FUEL CONSUMPTION BY SERVICES

104.15 Quantities of Coal and Coke Consumed by Different Services: By an elaborate process of classifying the data relating to delivery, consumption and distribution of coal and coke recorded on statistical cards, the quantity consumed by each important service during the year 1912 was determined. In this process six services, subdivided to present a statistical record under 15 different headings, were recognized. These services are as follows:

1. Steam locomotives.
2. Steam vessels.
3. High pressure steam stationary power and heating plants.
4. Low pressure steam and other stationary heating plants.
5. Gas and coke plants.
6. Furnaces for metallurgical, manufacturing and other processes.

The quantities of coal and coke consumed by steam locomotives and steam vessels were determined, as described in sections 104.05 and 104.09, on a basis of consumption. The determination of the amount of coal and coke consumed by the remaining services, high pressure steam plants, low pressure steam plants, gas and coke plants, and furnaces for special processes, was accomplished by tracing the revenue fuel delivered by rail and by water through the various channels of distribution to the industrial and domestic consumers. Coal dealers and industries, with few exceptions, furnished information which enabled the Committee to assign to the proper services the coal and coke unloaded from cars at their yards or plants. The coal and coke received by the small number of dealers and industries from whom the necessary information as to distribution could not be obtained, were apportioned to the different services on the basis of data obtained from other plants or dealers surrounded by similar conditions. The agencies, through which the data relating to distribution were obtained, included some 900 industries which received fuel in cars placed on railroad sidings at their plants, some 350 industrial plants which received fuel at team tracks, about 250 large coal dealers operating some 350 coal yards with track connections, and a much larger number of dealers and individuals who received fuel by the carload on public team tracks. This information was obtained both by mail and by personal solicitation by representatives of the Committee.

A summary showing the quantity of coal and coke consumed by the different services, and the quantities involved in the determination of the amounts of coal and coke consumed by high pressure steam stationary power and heating plants, by low pressure steam and other stationary heating plants, by gas and coke plants and by furnaces for metallurgical, manufacturing and other processes, is presented as table XLII.

A condensed summary showing the fuel consumed during the year 1912 by railroad locomotives and by all other classes of service combined, is presented, by zones, as table XLIII.

TABLE XLII. SUMMARY SHOWING THE DISTRIBUTION AND CONSUMPTION OF COAL AND COKE BY THE DIFFERENT SERVICES WITHIN THE AREA OF INVESTIGATION

Service	Net Total Deliveries, Tons	Increase or Decrease in Storage, Tons	Consumption by R. R. Plants not Reported in Deliveries, Tons	Converted into Gas, Coke and By-Products, Tons	Redistributed and Reappearing in Deliveries to High and Low Pressure Services, Tons	Net Total Consumption, Tons
Steam locomotives...	....	....	....	....	....	2,815,400
Steam vessels	....	....	....	....	....	92,368
High pressure steam stationary power and heating plants....	8,648,135	+ 10,308	509,507	....	....	9,147,334
Low pressure steam and other stationary heating plants	4,301,467	—332,432	13,011	....	....	4,646,910
Gas and coke plants....	1,172,616	+ 119,913	2,078	797,817	3,097	253,867
Furnaces for metallurgical, manufacturing and other processes..	4,224,177	— 28,830	....	....	....	4,253,007
Total amount of fuel consumed during 1912................						21,208,886

TABLE XLIII. COAL AND COKE CONSUMED BY STEAM LOCOMOTIVES AND BY ALL OTHER SERVICES

Service	Zone A Tons	Zone B Tons	Zones A and B Tons	Per Cent of Total
Steam locomotives......	2,099,044	716,356	2,815,400	13.27
All other services.......	15,483,479	2,910,007	18,393,486	86.73
Totals...............	17,582,523	3,626,363	21,208,886	100.00

A more complete statement of the record, by services, of the fuel consumed is presented as table XLIV. The colored plates, fig. 12, represent graphically the relative importance of the several services.

TABLE XLIV. QUANTITY OF COAL AND COKE CONSUMED BY EACH SERVICE WITHIN THE AREA OF INVESTIGATION DURING THE YEAR 1912

Service	Zone A		Zone B		Zones A and B	
	Tons	Per Cent	Tons	Per Cent	Tons	Per Cent
1	2	3	4	5	6	7
Steam Locomotives:						
Yard	1,049,516	5.97	313,987	8.66	1,363,503	6.43
Road freight	136,115	0.77	122,672	3.38	258,787	1.22
Freight transfer	354,802	2.02	124,936	3.45	479,738	2.26
Passenger transfer	21,370	0.12	175	0.00	21,545	0.10
Through passenger	176,761	1.01	63,527	1.75	240,288	1.13
Suburban passenger	155,327	0.88	36,045	0.99	191,372	0.90
Locomotive terminals	205,153	1.17	55,014	1.52	260,167	1.23
Totals	2,099,044	11.94	716,356	19.75	2,815,400	13.27
Steam Vessels:						
Tugs and lighters	35,153	0.20	8,825	0.24	43,978	0.21
River barges and dredges	10,525	0.06	1,214	0.03	11,739	0.06
Lake steamers and barges	35,697	0.20	954	0.03	36,651	0.17
Totals	81,375	0.46	10,993	0.30	92,368	0.44
High Pressure Steam Stationary Power and Heating Plants: Including public service corporation, municipal, steam railroad, office buildings, hotels, schools, power plants or boiler plants	7,316,257	41.61	1,831,077	50.51	9,147,344	43.13
Low Pressure Steam and Other Stationary Heating Plants: Including large and small buildings, large and small apartments and residences	4,154,746	23.63	492,164	13.57	4,646,910	21.91
Gas and Coke Plants:						
Public service, excluding boiler power plants	139,525	0.79	18,159	0.50	157,684	0.74
Other service, excluding boiler power plants	95,026	0.54	1,157	0.03	96,183	0.46
Totals	234,551	1.33	19,316	0.53	253,867	1.20
Furnaces for Metallurgical, Manufacturing and Other Processes: Including steel plants, foundries, forges and allied processes; brick, pottery and allied processes, and miscellaneous manufacturing, rendering and other processes, excluding boiler power plants	3,696,550	21.03	556,457	15.34	4,253,007	20.05
Totals	17,582,523	100.00	3,626,363	100.00	21,208,886	100.00

THE AMOUNT OF COAL AND COKE CONSUMED IN DIFFERENT DISTRICTS WITHIN THE AREA OF INVESTIGATION

104.16 Subdivision of Zones into Districts and Amount of Coal and Coke Consumed in Each District: For the purpose of making a comparison of the amounts of fuel consumed in different localities and of studying the distribution of the large quantities of coal and coke brought into the Area of Investigation, the two large zones were divided into districts called "Zone Districts." The boundaries of these zone districts were fixed after a careful study of conditions pertaining to the density of fuel consumption and the character of smoke emitted, Zone A being divided into 14 districts, numbered A–1 to A–14 inclusive, and Zone B into 13 districts, numbered B–1 to B–13 inclusive. Delimitations and numerical designations of the several zone districts are shown on the map presented as fig. 13.

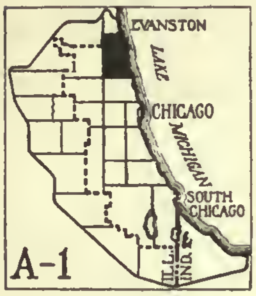
It is recognized that the statistics relating to coal and coke consumption by zone districts may contain a slight element of error due to the transportation of fuel over short distances from one district to another after being reported, and to the difficulty of applying district delimitations with exactness in the reports of dealers and consumers. Care was taken, however, to minimize the possibility of such errors, and the results are presented in detail as possessing sufficient accuracy for all practical purposes. These data do not, in any sense, form the basis of any of the broader computations, such as those involved in the determination of smoke discharges.

A brief description of each of the several zone districts and a summary showing the amount of fuel consumed in each district by different services are presented in the paragraphs which follow. In the summary presented for each zone district are shown the amount of fuel, in tons, consumed by steam locomotives, that consumed by all other services combined, the percentage of the total fuel in the district consumed by steam locomotives and by all other services combined, and the density, in tons per square mile, of the fuel consumption by steam locomotives and by all other services combined. A detailed statement of the fuel consumed by different services in each zone district, in which the tonnage of each kind of fuel consumed by each service is shown, is also presented.

FIG. 13. SUBDIVISION OF THE AREA OF INVESTIGATION INTO ZONE DISTRICTS

Zone District A-1

This district embraces an area of 16.08 square miles in the extreme northeastern corner of the city of Chicago, bounded by Lake Michigan, the northern city limits, Kedzie Avenue and Belmont Avenue. The eastern portion is well populated and is occupied by high grade residences, while the western portion is sparsely populated and contains many open fields. It is crossed by the main lines of two railroads, and contains several small railroad yards, a portion of Lincoln Park, three cemeteries and extensive boulevards. The following summary shows the fuel consumed by the different services in Zone District A-1:



Zone District A-1

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	14,877	2.42	925
All other services	600,527	97.58	37,346
Totals	615,404	100.00	38,271

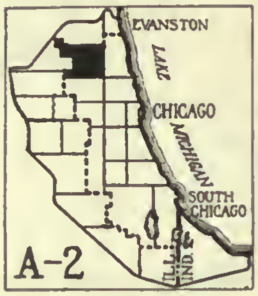
A detailed statement of the fuel consumed by different services in Zone District A-1 is presented as table XLV.

TABLE XLV. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A-1

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	4,460	4,460
Road freight	0	0	0	315	315
Freight transfer	0	0	0	340	340
Passenger transfer	0	0	0	141	141
Through passenger	0	0	0	2,570	2,570
Suburban passenger	0	0	0	7,051	7,051
Totals	0	0	0	14,877	14,877
Locomotive terminals	0	0	0	0	0
Totals	0	0	0	14,877	14,877
Steam Vessels:					
Tugs and lighters	7	0	89	1,386	1,482
River barges and dredges	0	0	167	163	330
Lake steamers and barges	0	0	0	72	72
Totals	7	0	256	1,621	1,884
High Pressure Steam Stationary Power and Heating Plants	821	0	5,999	128,087	134,907
Low Pressure Steam and other Stationary Heating Plants	207,344	6,880	122,745	120,423	457,392
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	2,430	20	0	3,894	6,344
Grand totals	210,602	6,900	129,000	268,902	615,404

Zone District A-2

This district has an area of 18.26 square miles and embraces within its boundaries the territory from Kedzie Avenue westward to the city limits and from the northern city limits southward to Belmont Avenue. Some portions of it are densely populated while other portions include large open unimproved areas. It is crossed by several railroad lines and contains a few railroad yards. A number of manufacturing plants and industrial establishments are located within its borders. The following summary shows the amount of fuel consumed by the different services in Zone District A-2:



Zone District A-2

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	40,561	33.67	2,221
All other services	79,903	66.33	4,376
Totals	120,464	100.00	6,597

A detailed statement of the fuel consumed by different services in Zone District A-2 is presented as table XLVI.

TABLE XLVI. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A-2

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	7,493	7,493
Road freight	0	0	0	14,971	14,971
Freight transfer	0	0	0	4,780	4,780
Passenger transfer	0	0	0	0	0
Through passenger	0	0	0	7,413	7,413
Suburban passenger	0	0	0	5,904	5,904
Totals	0	0	0	40,561	40,561
Locomotive terminals	0	0	0	0	0
Totals	0	0	0	40,561	40,561
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	2,237	7,436	9,673
Low Pressure Steam and other Stationary Heating Plants	36,065	1,006	1,862	12,563	51,496
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	0	20	0	18,714	18,734
Grand totals	36,065	1,026	4,099	79,274	120,464

Zone District A-3

This district has an area of 13.50 square miles and embraces the territory from Kedzie Avenue westward to the city limits and from Belmont Avenue southward to Chicago Avenue. Some portions of it are densely populated while others embrace open fields. Several railroad lines cross the area and a number of manufacturing plants and several railroad yards, including the Galewood yard of the Chicago, Milwaukee & St. Paul Railway, are located within it. The following summary shows the fuel consumed by the different services in Zone District A-3:

Zone District A-3

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	92,033	30.75	6,817
All other services	207,235	69.25	15,351
Totals	299,268	100.00	22,168

A detailed statement of the fuel consumed by different services in Zone District A-3 is presented as table XLVII.

TABLE XLVII. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A-3

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	48,165	48,165
Road freight	0	0	0	11,990	11,990
Freight transfer	0	0	0	15,715	15,715
Passenger transfer	0	0	0	947	947
Through passenger	0	0	0	5,062	5,062
Suburban passenger	0	0	0	2,734	2,734
Totals	0	0	0	84,613	84,613
Locomotive terminals	0	0	0	7,420	7,420
Totals	0	0	0	92,033	92,033
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	1,061	102,500	103,561
Low Pressure Steam and other Stationary Heating Plants	37,488	1,318	30,634	26,687	96,127
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	2,894	4,072	0	581	7,547
Grand totals	40,382	5,390	31.695	221.801	299,268

Zone District A-4

This district covers an area of 12.16 square miles extending from Lake Michigan to Kedzie Avenue and from Belmont Avenue to Chicago Avenue. It is densely populated. Included within its area are many coal and lumber yards, numerous manufacturing plants (some of which are large), many railroad lines and yards, and the north branch of the Chicago River with its extensive docks. It also contains Lincoln Park, the Lake Shore Drive and Humboldt Park. The following summary shows the fuel consumed in Zone District A-4:

Zone District A-4

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	62,391	2.91	5,131
All other services	2,079,574	97.09	171,017
Totals	2,141,965	100.00	176,148

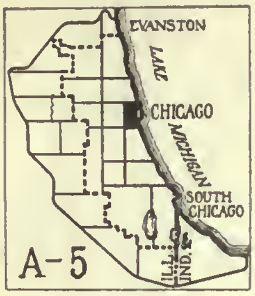
A detailed statement of the fuel consumed by different services in Zone District A-4 is presented as table XLVIII.

TABLE XLVIII. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A-4

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	28,629	28,629
Road freight	0	0	0	708	708
Freight transfer	0	0	0	7,830	7,830
Passenger transfer	0	0	0	502	502
Through passenger	0	0	0	6,336	6,336
Suburban passenger	0	0	0	9,148	9.148
Totals	0	0	0	53,153	53,153
Locomotive terminals	0	0	0	9,238	9,238
Totals	0	0	0	62,391	62,391
Steam Vessels:					
Tugs and lighters	11	0	859	3,693	4,563
River barges and dredges	0	0	289	7,957	8,246
Lake steamers and barges	0	0	0	477	477
Totals	11	0	1,148	12,127	13,286
High Pressure Steam Stationary Power and Heating Plants	101	0	109,450	883,158	992,709
Low Pressure Steam and other Stationary Heating Plants	542,160	4,157	141,025	212,269	899,611
Gas and Coke Plants:					
Public service	5,100	55,510	0	0	60,610
Other service	0	0	0	0	0
Totals	5,100	55,510	0	0	60,610
Furnaces:					
For metallurgical, manufacturing and other processes	16,917	23,176	124	73,141	113,358
Grand totals	564,289	82,843	251,747	1,243,086	2,141,965

Zone District A-5

This district has an area of 4.52 square miles bounded by the lake, Halsted Street, Chicago Avenue and 22d Street. It is densely populated. It embraces the most congested business portion of the city, known as the "Loop," with its many large office buildings, hotels, manufacturing buildings, power and heating plants, railroad terminals, and the Chicago River and Harbor with their almost continuous dock facilities and warehouses. The density of fuel consumption is higher than that of any other district. The following summary shows the fuel consumed in Zone District A-5:



Zone District A-5

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	258,641	14.78	57,221
All other services	1,491,354	85.22	329,946
Totals	1,749,995	100.00	387,167

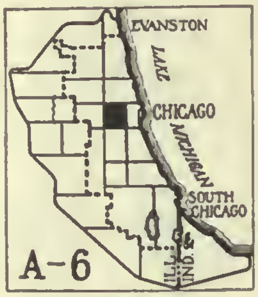
A detailed statement of the fuel consumed by different services in Zone District A-5 is presented as table XLIX.

TABLE XLIX. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A-5

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	11,684	143,084	154,768
Road freight	0	0	0	3,838	3,838
Freight transfer	0	0	571	15,797	16,368
Passenger transfer	0	0	885	7,738	8,623
Through passenger	0	0	407	24,188	24,595
Suburban passenger	0	0	0	24,454	24,454
Totals	0	0	13,547	219,099	232,646
Locomotive terminals	0	0	0	25,995	25,995
Totals	0	0	13,547	245,094	258,641
Steam Vessels:					
Tugs and lighters	51	0	2,318	12,408	14,777
River barges and dredges	0	0	416	467	883
Lake steamers and barges	0	0	0	19,192	19,192
Totals	51	0	2,734	32,067	34,852
High Pressure Steam Stationary Power and Heating Plants	0	0	74,799	1,201,804	1,276,603
Low Pressure Steam and other Stationary Heating Plants	7,983	2,101	16,878	141,472	168,434
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	1,133	10,276	0	56	11,465
Grand totals	9,167	12,377	107,958	1,620,493	1,749,995

Zone District A-6

Zone District A-6 embraces a territory of 9.00 square miles bounded by Halsted Street on the east, Chicago Avenue on the north, Kedzie Avenue on the west and 22d Street on the south. It includes extensive railroad trackage besides a number of large railroad yards. It is densely populated and is occupied by many manufacturing plants, power plants, large residential districts, one large park (Douglas), one small park (Union) and extensive boulevards. The following summary shows the fuel consumed in Zone District A-6:



Zone District A-6

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	262,365	18.92	29,152
All other services	1,124,659	81.08	124,962
Totals	1,387,024	100.00	154,114

A detailed statement of the fuel consumed by different services in Zone District A-6 is presented as table L.

TABLE L. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A-6

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	153,504	153,504
Road freight	0	0	0	4,315	4,315
Freight transfer	0	0	0	48,539	48,539
Passenger transfer	0	0	0	3,122	3,122
Through passenger	0	0	0	17,993	17,993
Suburban passenger	0	0	0	13,968	13,968
Totals	0	0	0	241,441	241,441
Locomotive terminals	0	0	0	20,924	20,924
Totals	0	0	0	262,365	262,365
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	1,232	691	32,734	390,828	425,485
Low Pressure Steam and other Stationary Heating Plants	235,517	6,346	105,437	278,087	625,387
Gas and Coke Plants:					
Public service	0	21,216	0	0	21,216
Other service	245	0	0	1,833	2,078
Totals	245	21,216	0	1,833	23,294
Furnaces:					
For metallurgical, manufacturing and other processes	9,877	37,298	275	3,043	50,493
Grand totals	246,871	65,551	138,446	936,156	1,387,024

Zone District A-7

This district has an area of 8.75 square miles, is located directly west of Zone District A-6, and covers the territory from Kedzie Avenue westward to the city limits and from Chicago Avenue southward to 22d Street. Portions of it are densely populated while other portions are sparsely populated and contain large open fields. It is crossed by several railroad lines. It contains a number of large railroad yards, including the 40th Avenue yard of the Chicago & Northwestern Railway, and numerous manufacturing plants. One large park (Garfield) and extensive boulevards are included within its borders. The following summary shows the fuel consumed in Zone District A-7:

Zone District A-7

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	138,972	24.70	15,883
All other services	423,679	75.30	48,421
Totals	562,651	100.00	64,303

A detailed statement of the fuel consumed by different services in Zone District A-7 is presented as table LI.

TABLE LI. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A-7

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	78,898	78,898
Road freight	0	0	0	4,314	4,314
Freight transfer	0	0	0	23,925	23,925
Passenger transfer	0	0	0	131	131
Through passenger	0	0	0	5,382	5,382
Suburban passenger	0	0	0	3,470	3,470
Totals	0	0	0	116,120	116,120
Locomotive terminals	0	0	0	22,852	22,852
Totals	0	0	0	138,972	138,972
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	2,770	227,379	230,149
Low Pressure Steam and other Stationary Heating Plants	84,832	3,599	25,440	78,197	192,068
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	79	1,329	0	54	1,462
Grand totals	84,911	4,928	28,210	444,602	562,651

Zone District A-8

This district, embracing an area of 15.50 square miles, extends from Kedzie Avenue westward to the city limits and from 22d Street southward to the city limits. Excepting in the northern portion it is sparsely populated. It includes a number of railroad lines and yards, notably the Corwith yard and, farther south, the Elsdon yard of the Grand Trunk Western Railway. Within its boundaries are an occasional manufacturing plant and a portion of one large park (Marquette). The open fields in this district are extensive. The following summary shows the amount of fuel consumed by the different services in Zone District A-8:

Zone District A-8

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	85,288	49.39	5,502
All other services	87,390	50.61	5,639
Totals	172,678	100.00	11,141

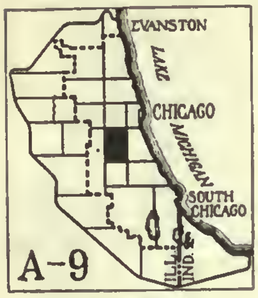
A detailed statement of the fuel consumed by different services in Zone District A-8 is presented as table LII.

TABLE LII. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A-8

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	8,741	22,640	31,381
Road freight	0	0	0	9,442	9,442
Freight transfer	0	0	571	26,517	27,088
Passenger transfer	0	0	0	51	51
Through passenger	0	0	712	4,340	5,052
Suburban passenger	0	0	0	4,084	4,084
Totals	0	0	10,024	67,074	77,098
Locomotive terminals	0	0	0	8,190	8,190
Totals	0	0	10,024	75,264	85,288
Steam Vessels:					
Tugs and lighters	5	0	88	687	780
River barges and dredges	0	0	30	71	101
Lake steamers and barges	0	0	0	0	0
Totals	5	0	118	858	881
High Pressure Steam Stationary Power and Heating Plants	0	0	63	21,964	22,027
Low Pressure Steam and other Stationary Heating Plants	13,055	302	2,181	39,954	55,492
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	0	8,956	0	34	8,990
Grand totals	13,060	9,258	12,386	137,974	172,678

Zone District A-9

This district has an area of 12.00 square miles, extending from Halsted Street to Kedzie Avenue and from 22d Street to 55th Street. Included within its borders are the Stockyards, the Central Manufacturing District, many railroad terminals and yards, manufacturing plants, power plants, coal and lumber yards, the south branch of the Chicago River, parts of the Drainage Canal and the Illinois and Michigan Canal, McKinley and Sherman parks and three boulevards. The following summary shows the fuel consumed in Zone District A–9:



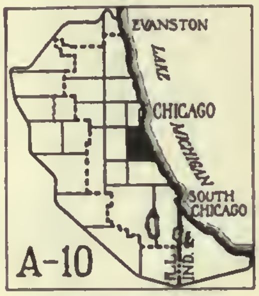
Zone District A-9

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ.MI.
Steam locomotives	223,732	7.58	18,444
All other services	2,727,295	92.42	227,275
Totals	2,951,027	100.00	245,919

A detailed statement of the fuel consumed by different services in Zone District A–9 is presented as table LIII.

Zone District A-10

This district embraces an area of 9.58 square miles bounded by Lake Michigan on the east, 22d Street on the north, Halsted Street on the west and 55th Street on the south. It is very densely populated, and is occupied by many large buildings, numerous apartment houses, some manufacturing plants, many railroad lines and yards, extensive boulevards and a portion of one large park (Washington). Many high grade residences and several large hotels are located in this district. The following summary shows the fuel consumed in Zone District A–10:



Zone District A-10

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ.MI.
Steam locomotives	238,919	16.90	24,939
All other services	1,174,894	83.10	122,641
Totals	1,413,813	100.00	147,580

A detailed statement of the fuel consumed by different services in Zone District A–10 is presented as table LIV.

TABLE LIII. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A–9

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	155,438	155,438
Road freight	0	0	0	5,581	5,581
Freight transfer	0	0	1,569	42,287	43,856
Passenger transfer	0	0	0	501	501
Through passenger	0	0	1,119	5,370	6,489
Suburban passenger	0	0	0	2,103	2,103
Totals	0	0	2,688	211,280	213,968
Locomotive terminals	0	0	0	9,764	9,764
Totals	0	0	2,688	221,044	223,732
Steam Vessels:					
Tugs and lighters	22	0	246	3,889	4,157
River barges and dredges	0	0	228	290	518
Lake steamers and barges	0	0	0	2,615	2,615
Totals	22	0	474	6,794	7,290
High Pressure Steam Stationary Power and Heating Plants	107	0	4,560	2,320,965	2,325,632
Low Pressure Steam and other Stationary Heating Plants	19,468	1,997	13,354	200,387	235,206
Gas and Coke Plants:					
Public service	782	45,016	0	0	45,798
Other service	0	0	0	0	0
Totals	782	45,016	0	0	45,798
Furnaces:					
For metallurgical, manufacturing and other processes	3,106	33,071	706	76,486	113,369
Grand totals	23,485	80,084	21,782	2,825,676	2,951,027

TABLE LIV. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A–10

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	79,050	79,050
Road freight	0	0	0	9,117	9,117
Freight transfer	0	0	285	34,380	34,665
Passenger transfer	0	0	0	5,203	5,203
Through passenger	0	0	203	35,959	36,162
Suburban passenger	0	0	0	33,016	33,016
Totals	0	0	488	196,725	197,213
Locomotive terminals	0	0	0	41,706	41,706
Totals	0	0	488	238,431	238,919
Steam Vessels:					
Tugs and lighters	5	0	53	927	985
River barges and dredges	0	0	56	100	156
Lake steamers and barges	0	0	0	705	705
Totals	5	0	109	1,732	1,846
High Pressure Steam Stationary Power and Heating Plants	0	0	19,094	552,874	571,968
Low Pressure Steam and other Stationary Heating Plants	182,309	4,034	122,385	283,968	592,696
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	165	5,913	0	2,306	8,384
Grand totals	182,479	9,947	142,076	1,079,311	1,413,813

Zone District A-11

The territory embraced by this district has an area of 12.36 square miles and is bounded by Lake Michigan on the east, 55th Street on the north, Halsted Street on the west and 79th Street on the south. It is densely populated and includes a few manufacturing plants, many railroad lines and railroad yards, one large park (Jackson), a portion of another park (Washington), two small parks, extensive boulevards and drives, the University of Chicago, and many high grade residences. The following summary shows the fuel consumed by the different services in Zone District A-11:

Zone District A-11

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	129,509	16.64	10,478
All other services	648,562	83.36	52,473
Totals	778,071	100.00	62,951

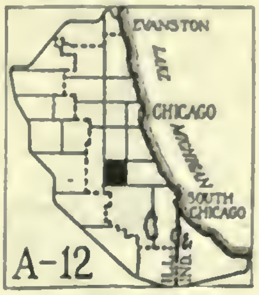
A detailed statement of the fuel consumed by different services in Zone District A-11 is presented as table LV.

TABLE LV. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A-11

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	29,963	29,963
Road freight	0	0	0	12,516	12,516
Freight transfer	0	0	0	26,623	26,623
Passenger transfer	0	0	0	1,317	1,317
Through passenger	0	0	0	18,860	18,860
Suburban passenger	0	0	0	20,278	20,278
Totals	0	0	0	109,557	109,557
Locomotive terminals	0	0	0	19,952	19,952
Totals	0	0	0	129,509	129,509
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	8,709	135,169	143,878
Low Pressure Steam and other Stationary Heating Plants	119,322	6,400	248,682	126,801	501,205
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	1,330	2,126	0	23	3,479
Grand totals	120,652	8,526	257,391	391,502	778,071

Zone District A-12

This district, covering an area of 9.00 square miles, includes the territory from Halsted Street westward to Kedzie Avenue and from 55th Street southward to 79th Street. It is occupied by a few manufacturing plants, several railroad lines, a portion of one large park (Marquette), one small park (Ogden) and extensive boulevards. Portions of this district are well covered with buildings and residences, while other sections present areas of open and unimproved land. The following summary shows the fuel consumed by different services in Zone District A-12:



Zone District A-12

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	78,090	56.95	8,677
All other services	59,042	43.05	6,560
Totals	137,132	100.00	15,237

A detailed statement of the fuel consumed by different services in Zone District A-12 is presented as table LVI.

TABLE LVI. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A-12

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	42,569	42,569
Road freight	0	0	0	4,729	4,729
Freight transfer	0	0	0	17,016	17,016
Passenger transfer	0	0	0	39	39
Through passenger	0	0	0	1,545	1,545
Suburban passenger	0	0	0	896	896
Totals	0	0	0	66,794	66,794
Locomotive terminals	0	0	0	11,296	11,296
Totals	0	0	0	78,090	78,090
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	0	5,630	5,630
Low Pressure Steam and other Stationary Heating Plants	23,520	319	7,909	20,253	52,001
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	0	547	0	864	1,411
Grand totals	23,520	866	7,909	104,837	137,132

Zone District A-13

The territory embraced in this district covers an area of 33.55 square miles and extends from Stony Island Avenue and the western line of Sections 13, 24, 25 and 36, Twp. 37 N., R. 14 E., westward to Kedzie Avenue and the city limits and from 79th Street southward to the city limits. It includes Morgan Park but does not include a small area lying between Morgan Park and Chicago. It is crossed by several railroad lines. Many manufacturing plants with special furnaces are located within its borders. The following summary shows the fuel consumed in Zone District A-13:

Zone District A-13

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	260,891	36.38	7,776
All other services	456,326	63.62	13,602
Totals	717,217	100.00	21,378

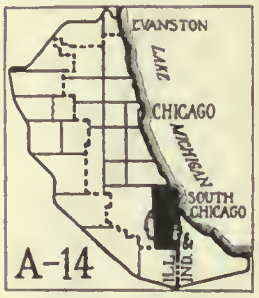
A detailed statement of the fuel consumed by different services in Zone District A-13 is presented as table LVII.

TABLE LVII. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A-13

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	102,107	102,107
Road freight	0	0	0	34,648	34,648
Freight transfer	0	0	0	60,480	60,480
Passenger transfer	0	0	0	687	687
Through passenger	0	0	0	22,865	22,865
Suburban passenger	0	0	0	22,018	22,018
Totals	0	0	0	242,805	242,805
Locomotive terminals	0	0	0	18,086	18,086
Totals	0	0	0	260,891	260,891
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	3,030	1,430	666	283,927	289,053
Low Pressure Steam and other Stationary Heating Plants	44,936	2,168	5,300	71,039	123,443
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	263	19,609	0	23,953	43,830
Grand totals	48,234	23,207	5,966	639,810	717,217

Zone District A-14

This district embraces an area of 20.16 square miles and includes the territory from Lake Michigan and the state line westward to Stony Island Avenue and the western line of Sections 13, 24, 25 and 36, Twp. 37 N., R. 14 E., and from 79th Street southward to the city limits. Within its area are located the industries of South Chicago and the extensive docks for ore and coal along the Calumet River. It contains many large steel and industrial plants, many railroad lines and extensive railroad yards. The following summary shows the fuel consumed in Zone District A-14:



Zone District A-14

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	212,775	4.69	10,554
All other services	4,323,039	95.31	214,437
Totals	4,535,814	100.00	224,991

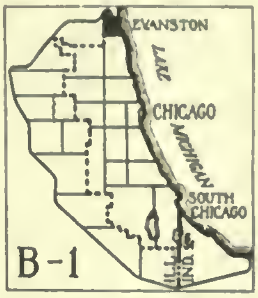
A detailed statement of the fuel consumed by different services in Zone District A-14 is presented as table LVIII.

TABLE LVIII. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT A-14

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	2,624	130,467	133,091
Road freight	0	0	0	19,631	19,631
Freight transfer	0	0	0	27,577	27,577
Passenger transfer	0	0	0	106	106
Through passenger	0	0	0	16,437	16,437
Suburban passenger	0	0	0	6,203	6,203
Totals	0	0	2,624	200,421	203,045
Locomotive terminals	0	0	0	9,730	9,730
Totals	0	0	2,624	210,151	212,775
Steam Vessels:					
Tugs and lighters	11	0	95	8,303	8,409
River barges and dredges	0	0	0	291	291
Lake steamers and barges	0	0	0	12,636	12,636
Totals	11	0	95	21,230	21,336
High Pressure Steam Stationary Power and Heating Plants	0	0	54	784,928	784,982
Low Pressure Steam and other Stationary Heating Plants	23,762	554	5,353	74,519	104,188
Gas and Coke Plants:					
Public service	0	11,901	0	0	11,901
Other service	0	0	2,366	90,582	92,948
Totals	0	11,901	2,366	90,582	104,849
Furnaces:					
For metallurgical, manufacturing and other processes	5,512	2,775,944	25,585	500,643	3,307,684
Grand totals	29,285	2,788,399	36,077	1,682,053	4,535,814

Zone District B-1

This district has an area of 5.28 square miles and embraces the territory from Lake Michigan westward to Kedzie Avenue extended and from the northern city limits northward to the outer boundary of Zone B. It is crossed by two lines of railroad and includes within its borders a few manufacturing and power plants. The district is almost entirely residential and is thickly populated. It includes a large portion of the city of Evanston. The following summary shows the amount of fuel consumed by the different services in Zone District B-1:



Zone District B-1

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	11,482	8.30	2,175
All other services	126,886	91.70	24,031
Totals	138,368	100.00	26,206

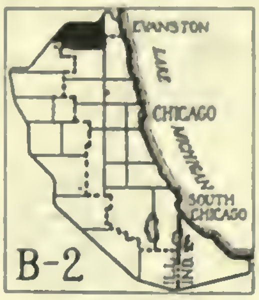
A detailed statement of the fuel consumed by different services in Zone District B-1 is presented as table LIX.

TABLE LIX. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B-1

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	4,188	4,188
Road freight	0	0	0	386	386
Freight transfer	0	0	0	23	23
Passenger transfer	0	0	0	53	53
Through passenger	0	0	0	2,434	2,434
Suburban passenger	0	0	0	3,454	3,454
Totals	0	0	0	10,538	10,538
Locomotive terminals	0	0	0	944	944
Totals	0	0	0	11,482	11,482
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	2,607	22,462	25,069
Low Pressure Steam and other Stationary Heating Plants	52,274	3,219	16,439	15,732	87,664
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	0	0	0	14,153	14,153
Grand totals	52,274	3,219	19,046	63,829	138,368

Zone District B-2

This district embraces an area of 15.93 square miles extending from Kedzie Avenue and Kedzie Avenue extended, westward to a portion of Chicago known as Edison Park and to the outer boundary of Zone B, and from the northern city limits and Park Ridge Road northward to the boundary of Zone B. It has a small population centered principally at Morton Grove and Niles Center. The district contains large areas of farm lands. It is crossed by the main lines of several railroads. The following summary shows the fuel consumed in Zone District B-2:



Zone District B-2

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	11,780	19.55	739
All other services	48,483	80.45	3,044
Totals	60,263	100.00	3,783

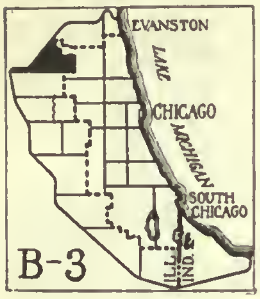
A detailed statement of the fuel consumed by different services in Zone District B-2 is presented as table LX.

TABLE LX. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B-2

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	0	0
Road freight	0	0	0	6,536	6,536
Freight transfer	0	0	0	19	19
Passenger transfer	0	0	0	0	0
Through passenger	0	0	0	3,948	3,948
Suburban passenger	0	0	0	1,277	1,277
Totals	0	0	0	11,780	11,780
Locomotive terminals	0	0	0	0	0
Totals	0	0	0	11,780	11,780
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	78	30,438	30,516
Low Pressure Steam and other Stationary Heating Plants	389	0	90	16,161	16,640
Gas and Coke Plants:					
Public service	0	663	0	0	663
Other service	0	0	0	0	0
Totals	0	663	0	0	663
Furnaces:					
For metallurgical, manufacturing and other processes	0	505	0	159	664
Grand totals	389	1,168	168	58,538	60,263

Zone District B-3

This district has an area of 14.59 square miles extending from the city limits westward to the outer boundary of Zone B and from Park Ridge Road southward to Irving Park Boulevard and Seymour Avenue. It has a small population, chiefly in Park Ridge. The territory consists mainly of farm lands. It is crossed by two railroads. The following summary shows the fuel consumed in Zone District B-3:



Zone District B-3

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	11,499	26.46	788
All other services	31,959	73.54	2,191
Totals	43,458	100.00	2,979

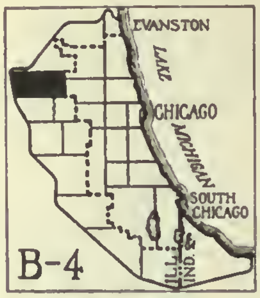
A detailed statement of the fuel consumed by different services in Zone District B-3 is presented as table LXI.

TABLE LXI. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B-3

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahoatas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	5,631	5,631
Road freight	0	0	0	1,118	1,118
Freight transfer	0	0	0	125	125
Passenger transfer	0	0	0	0	0
Through passenger	0	0	0	1,008	1,008
Suburban passenger	0	0	0	703	703
Totals	0	0	0	8,585	8,585
Locomotive terminals	0	0	0	2,914	2,914
Totals	0	0	0	11,499	11,499
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	1,404	22,257	23,661
Low Pressure Steam and other Stationary Heating Plants	4,869	333	2,205	891	8,298
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	0	0	0	0	0
Grand totals	4,869	333	3,609	34,647	43,458

Zone District B-4

This district covers an area of 19.25 square miles extending from the city limits westward to the outer boundary of Zone B and from Irving Park Boulevard and Seymour Avenue southward to North Avenue. Its small population is centered principally in the villages of Franklin Park and River Grove. The remaining territory contains tracts of farm lands. It is crossed by the main lines of three railroads and by the Des Plaines River. The following summary shows the fuel consumed in Zone District B-4:



Zone District B-4

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	30,552	68.65	1,587
All other services	13,950	31.35	725
Totals	44,502	100.00	2,312

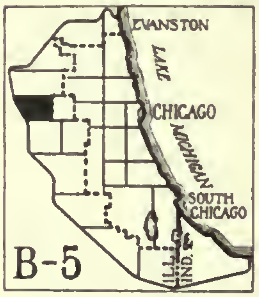
A detailed statement of the fuel consumed by different services in Zone District B-4 is presented as table LXII.

TABLE LXII. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B-4

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	11,519	11,519
Road freight	0	0	0	5,326	5,326
Freight transfer	0	0	0	5,418	5,418
Passenger transfer	0	0	0	0	0
Through passenger	0	0	0	3,767	3,767
Suburban passenger	0	0	0	1,613	1,613
Totals	0	0	0	27,643	27,643
Locomotive terminals	0	0	0	2,909	2,909
Totals	0	0	0	30,552	30,552
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	0	5,925	5,925
Low Pressure Steam and other Stationary Heating Plants	1,298	179	135	6,176	7,788
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	0	237	0	0	237
Grand totals	1,298	416	135	42,653	44,502

Zone District B-5

The territory embraced in this district contains an area of 11.84 square miles located directly west of the Des Plaines River and extending from the river westward to the outer boundary of Zone B and from North Avenue southward



Zone District B-5

to 12th Street. Its centers of population are Melrose Park, Maywood and Bellwood. It contains large areas of farm lands and a few manufacturing plants. It is crossed by the main lines of three railroads. The following summary shows the fuel consumed in Zone District B–5:

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	46,630	30.71	3,938
All other services	105,224	69.29	8,888
Totals	151,854	100.00	12,826

A detailed statement of the fuel consumed by different services in Zone District B–5 is presented as table LXIII.

TABLE LXIII. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B–5

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	26,525	26,525
Road freight	0	0	0	3,957	3,957
Freight transfer	0	0	0	10,163	10,163
Passenger transfer	0	0	0	0	0
Through passenger	0	0	0	2,900	2,900
Suburban passenger	0	0	0	1,705	1,705
Totals	0	0	0	45,250	45,250
Locomotive terminals	0	0	0	1,380	1,380
Totals	0	0	0	46,630	46,630
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	238	68,102	68,340
Low Pressure Steam and other Stationary Heating Plants	18,687	666	2,459	7,989	29,801
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	115	6,194	0	774	7,083
Grand totals	18,802	6,860	2,697	123,495	151,854

Zone District B-6

This district contains an area of 8.16 square miles embracing the territory from the city limits westward to the Des Plaines River and from North Avenue southward to 12th Street. It is crossed by several railroad lines and contains the populous centers of Oak Park, River Forest and Forest Park. Its northern portion has many open fields. The following summary shows the fuel consumed by the different services in Zone District B–6:

Zone District B-6

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	18,847	9.48	2,310
All other services	180,010	90.52	22,060
Totals	198,857	100.00	24,370

A detailed statement of the fuel consumed by different services in Zone District B–6 is presented as table LXIV.

TABLE LXIV. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B–6

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminnus	
Steam Locomotives:					
Yard	0	0	0	1,820	1,820
Road freight	0	0	0	3,817	3,847
Freight transfer	0	0	0	7,135	7,135
Passenger transfer	0	0	0	0	0
Through passenger	0	0	0	4,085	4,085
Suburban passenger	0	0	0	1,960	1,960
Totals	0	0	0	18,847	18,847
Locomotive terminals	0	0	0	0	0
Totals	0	0	0	18,847	18,847
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	1,906	58,193	60,099
Low Pressure Steam and other Stationary Heating Plants	59,059	2,680	14,086	34,695	110,520
Gas and Coke Plants:					
Public service	0	9,391	0	0	9,391
Other service	0	0	0	0	0
Totals	0	9,391	0	0	9,391
Furnaces:					
For metallurgical, manufacturing and other processes	0	0	0	0	0
Grand totals	59,059	12,071	15,992	111,735	198,857

Zone District B-7

This district contains an area of 16.48 square miles located directly west of Harlem Avenue, and extends from Harlem Avenue to the outer boundary of Zone B and from 12th Street southward to 47th Street. Its centers of population are the towns of Riverside, Brookfield, La Grange and La Grange Park. It includes large areas of farm lands. The district is crossed by several railroad lines and by the Des Plaines River. The following summary shows the amount of fuel consumed by the different services in Zone District B–7:

Zone District B-7

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	20,553	32.99	1,247
All other services	41,739	67.01	2,533
Totals	62,292	100.00	3,780

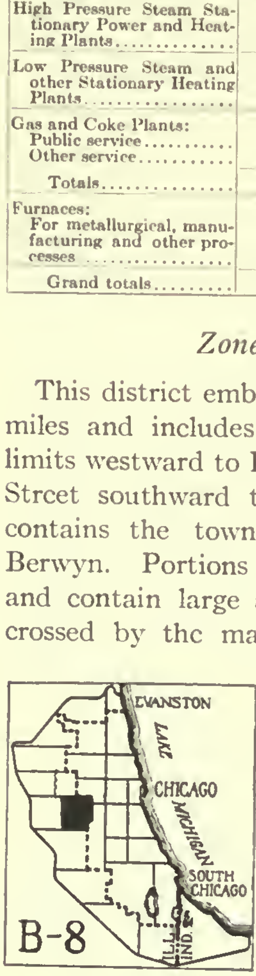
A detailed statement of the fuel consumed by different services in Zone District B-7 is presented as table LXV.

TABLE LXV. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B-7

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	0	0
Road freight	0	0	0	7,381	7,381
Freight transfer	0	0	0	5,162	5,162
Passenger transfer	0	0	0	0	0
Through passenger	0	0	0	3,492	3,492
Suburban passenger	0	0	0	4,518	4,518
Totals	0	0	0	20,553	20,553
Locomotive terminals	0	0	0	0	0
Totals	0	0	0	20,553	20,553
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	423	87	7,935	8,445
Low Pressure Steam and other Stationary Heating Plants	18,319	4,456	1,554	7,305	31,634
Gas and Coke Plants:					
Public service	0	1,660	0	0	1,660
Other service	0	0	0	0	0
Totals	0	1,660	0	0	1,660
Furnaces:					
For metallurgical, manufacturing and other processes	0	0	0	0	0
Grand totals	18,319	6,539	1,641	35,793	62,292

Zone District B-8

This district embraces an area of 12.75 square miles and includes the territory from the city limits westward to Harlem Avenue and from 12th Street southward to 47th Street. The district contains the towns of Hawthorne, Clyde and Berwyn. Portions of it are sparsely populated and contain large areas of open fields. It is crossed by the main lines of several railroads, along which a few manufacturing plants and railroad yards are located, and by the Drainage Canal, the Illinois and Michigan Canal and the Ogden Ditch. The following summary shows the fuel consumed by the different services in Zone District B-8:



Zone District B-8

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	61,992	26.49	4,862
All other services	172,011	73.51	13,491
Totals	234,003	100.00	18,353

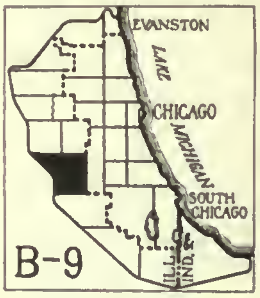
A detailed statement of the fuel consumed by different services in Zone District B-8 is presented as table LXVI.

TABLE LXVI. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B-8

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	33,058	33,058
Road freight	0	0	0	9,080	9,080
Freight transfer	0	0	0	8,377	8,377
Passenger transfer	0	0	0	0	0
Through passenger	0	0	0	5,458	5,458
Suburban passenger	0	0	0	5,218	5,218
Totals	0	0	0	61,191	61,191
Locomotive terminals	0	0	0	731	731
Totals	0	0	0	61,922	61,922
Steam Vessels:					
Tugs and lighters	5	0	92	716	813
River barges and dredges	0	0	32	74	106
Lake steamers and barges	0	0	0	0	0
Totals	5	0	124	790	919
High Pressure Steam Stationary Power and Heating Plants	0	0	78	93,789	93,867
Low Pressure Steam and other Stationary Heating Plants	13,140	1,170	1,258	18,751	34,319
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	233	12,472	162	30,109	42,976
Grand totals	13,378	13,642	1,622	205,361	234,003

Zone District B-9

The territory of 24.00 square miles embraced by this district extends from the city limits westward to the outer boundary of Zone B and from 47th Street southward to 87th Street. It is sparsely populated. It is crossed by the Drainage Canal, the Illinois and Michigan Canal, the Des Plaines River and several railroad lines. The following summary shows the amount of fuel consumed in Zone District B-9:



Zone District B-9

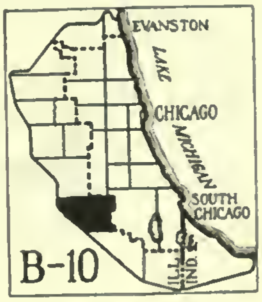
	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	32,169	16.07	1,340
All other services	167,953	83.93	6,998
Totals	200,122	100.00	8,338

A detailed statement of the fuel consumed by different services in Zone District B-9 is presented as table LXVII.

TABLE LXVII. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B-9

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminnus	
Steam Locomotives:					
Yard	0	0	0	12,516	12,516
Road freight	0	0	0	5,068	5,068
Freight transfer	0	0	0	11,616	11,616
Passenger transfer	0	0	0	0	0
Through passenger	0	0	0	1,721	1,721
Suburban passenger	0	0	0	170	170
Totals	0	0	0	31,091	31,091
Locomotive terminals	0	0	0	1,078	1,078
Totals	0	0	0	32,169	32,169
Steam Vessels:					
Tugs and lighters	7	0	142	1,117	1,266
River barges and dredges	0	0	50	116	166
Lake steamers and barges	0	0	0	0	0
Totals	7	0	192	1,233	1,432
High Pressure Steam Stationary Power and Heating Plants	0	0	0	160,511	160,511
Low Pressure Steam and other Stationary Heating Plants	660	30	55	4,611	5,356
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	104	83	0	467	654
Grand totals	771	113	247	198,991	200,122

Zone District B-10



Zone District B-10

This district covers an area of 21.57 square miles extending from the city limits westward to the outer boundary of Zone B and from 87th Street southward to 119th Street. Except for a small population in the towns of Evergreen Park, Mt. Greenwood and Oaklawn, the territory abounds in open fields and farm lands. Three railroad lines cross this district and Stony Creek flows through the southern portion. The following summary shows the fuel consumed in Zone District B-10:

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	18,656	93.85	865
All other services	1,223	6.15	57
Totals	19,879	100.00	922

A detailed statement of the fuel consumed by different services in Zone District B-10 is presented as table LXVIII.

TABLE LXVIII. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B-10

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	0	0
Road freight	0	0	0	5,788	5,788
Freight transfer	0	0	0	9,109	9,109
Passenger transfer	0	0	0	0	0
Through passenger	0	0	0	1,784	1,784
Suburban passenger	0	0	0	1,975	1,975
Totals	0	0	0	18,656	18,656
Locomotive terminals	0	0	0	0	0
Totals	0	0	0	18,656	18,656
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	0	451	451
Low Pressure Steam and other Stationary Heating Plants	80	0	130	387	597
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	0	0
Totals	0	0	0	0	0
Furnaces:					
For metallurgical, manufacturing and other processes	0	175	0	0	175
Grand totals	80	175	130	19,494	19,879

Zone District B-11

Zone District B-11

This district embraces an area of 20.32 square miles extending from the city limits and the extension of Indiana Avenue, westward to the outer boundary line of Zone B and from the city limits and 119th Street southward to the boundary line of Zone B. It contains the towns of Blue Island, Riverdale, Harvey, North Harvey, Posen and Phœnix. The remaining territory consists of open fields and marshy lands. Several railroad lines, on which are situated a number of manufacturing plants, cross the district, as do also the Little Calumet River, Stony Creek, Canal Feeder and Calumet Slough. The following summary shows the fuel consumed in Zone District B-11:

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	99,823	31.82	4,913
All other services	213,857	68.18	10,524
Totals	313,680	100.00	15,437

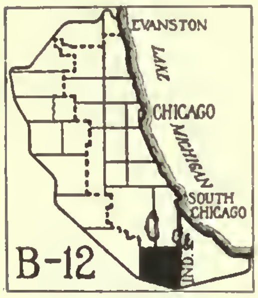
A detailed statement of the fuel consumed by different services in Zone District B-11 is presented as table LXIX.

TABLE LXIX. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B-11

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	45,907	45,907
Road freight	0	0	0	16,349	16,349
Freight transfer	0	0	0	18,434	18,434
Passenger transfer	0	0	0	4	4
Through passenger	0	0	0	4,547	4,547
Suburban passenger	0	0	0	6,139	6,139
Totals	0	0	0	91,380	91,380
Locomotive terminals	0	0	0	8,443	8,443
Totals	0	0	0	99,823	99,823
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	222	167,149	167,371
Low Pressure Steam and other Stationary Heating Plants	8,502	314	352	25,339	34,507
Gas and Coke Plants:					
Public service	0	4,466	0	0	4,466
Other service	0	0	0	0	0
Totals	0	4,466	0	0	4,466
Furnaces:					
For metallurgical, manufacturing and other processes	143	2,904	0	4,466	7,513
Grand totals	8,645	7,684	574	296,777	313,680

Zone District B-12

This district has an area of 21.28 square miles extending from the state line westward to the extension of Indiana Avenue and from the city limits southward to the outer boundary of Zone B. It is crossed by several railroad lines along which are located a number of manufacturing plants. With the exception of portions of the towns of Dolton, West Hammond, Calumet and Burnham, the district is sparsely populated. The following summary shows the amount of fuel consumed by the different services in Zone District B–12:



Zone District B-12

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	87,421	79.09	4,108
All other services	23,109	20.91	1,086
Totals	110,530	100.00	5,194

A detailed statement of the fuel consumed by different services in Zone District B–12 is presented as table LXX.

TABLE LXX. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B-12

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	45,136	45,136
Road freight	0	0	0	12,728	12,728
Freight transfer	0	0	0	16,435	16,435
Passenger transfer	0	0	0	24	24
Through passenger	0	0	0	6,588	6,588
Suburban passenger	0	0	0	1,012	1,012
Totals	0	0	0	81,923	81,923
Locomotive terminals	0	0	0	5,498	5,498
Totals	0	0	0	87,421	87,421
Steam Vessels:					
Tugs and lighters	0	0	0	0	0
River barges and dredges	0	0	0	0	0
Lake steamers and barges	0	0	0	0	0
Totals	0	0	0	0	0
High Pressure Steam Stationary Power and Heating Plants	0	0	0	17,124	17,124
Low Pressure Steam and other Stationary Heating Plants	1,972	50	85	2,721	4,828
Gas and Coke Plants:					
Public service	0	0	0	0	0
Other service	0	0	0	1,157	1,157
Totals	0	0	0	1,157	1,157
Furnaces:					
For metallurgical, manufacturing and other processes	0	0	0	0	0
Grand totals	1,972	50	85	108,423	110,530

Zone District B-13

This district has an area of 42.35 square miles embracing all of that portion of the Area of Investigation lying in the state of Indiana. Located within this territory are many large manufacturing and industrial plants and numerous railroad lines and railroad yards. Its centers of population are Hammond, East Chicago, Whiting and Indiana Harbor. The following summary shows the fuel consumed in Zone District B-13:

Zone District B-13

	TONS	PER CENT OF TOTAL	DENSITY OF CONSUMPTION, TONS PER SQ. MI.
Steam locomotives	265,022	12.94	6,258
All other services	1,783,533	87.06	42,114
Totals	2,048,555	100.00	48,372

A detailed statement of the fuel consumed by different services in Zone District B–13 is presented as table LXXI.

104.17 Summary of Results: Detailed statements setting forth the amount and kind of fuel consumed by different services in each zone are presented as tables LXXII and LXXIII, and in Zones A and B combined as table LXXIV.

TABLE LXXI. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE DISTRICT B-13

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	127,687	127,687
Road freight	0	0	0	45,108	45,108
Freight transfer	0	0	0	32,920	32,920
Passenger transfer	0	0	0	94	94
Through passenger	0	0	0	21,795	21,795
Suburban passenger	0	0	0	6,301	6,301
Totals	0	0	0	233,905	233,905
Locomotive terminals	0	0	0	31,117	31,117
Totals	0	0	0	265,022	265,022
Steam Vessels:					
Tugs and lighters	0	0	0	6,746	6,746
River barges and dredges	0	0	0	942	942
Lake steamers and barges	0	0	0	954	954
Totals	0	0	0	8,642	8,642
High Pressure Steam Stationary Power and Heating Plants	0	0	8,204	1,161,494	1,169,698
Low Pressure Steam and other Stationary Heating Plants	14,262	799	1,695	103,456	120,212
Gas and Coke Plants:					
Public service	0	1,979	0	0	1,979
Other service	0	0	0	0	0
Totals	0	1,979	0	0	1,979
Furnaces:					
For metallurgical, manufacturing and other processes	38	281,403	200	201,361	483,002
Grand totals	14,300	234,181	10,099	1,739,975	2,048,555

TABLE LXXII. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE A

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	23,049	1,026,467	1,049,516
Road freight	0	0	0	136,115	136,115
Freight transfer	0	0	2,996	351,806	354,802
Passenger transfer	0	0	885	20,485	21,370
Through passenger	0	0	2,441	174,320	176,761
Suburban passenger	0	0	0	155,327	155,327
Totals	0	0	29,371	1,864,520	1,893,891
Locomotive terminals	0	0	0	205,153	205,153
Totals	0	0	29,371	2,069,673	2,099,044
Steam Vessels:					
Tugs and lighters	112	0	3,748	31,293	35,153
River barges and dredges	0	0	1,186	9,339	10,525
Lake steamers and barges	0	0	0	35,697	35,697
Totals	112	0	4,934	76,329	81,375
High Pressure Steam Stationary Power and Heating Plants	5,291	2,121	262,196	7,046,649	7,316,257
Low Pressure Steam and other Stationary Heating Plants	1,577,761	41,181	849,185	1,686,619	4,154,746
Gas and Coke Plants:					
Public service	5,882	133,643	0	0	139,525
Other service	245	0	2,366	92,415	95,026
Totals	6,127	133,643	2,366	92,415	234,551
Furnaces:					
For metallurgical, manufacturing and other processes	43,711	2,922,357	26,690	703,792	3,696,550
Grand totals	1,633,002	3,099,302	1,174,742	11,675,477	17,582,523

TABLE LXXIII. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONE B

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	0	313,987	313,987
Road freight	0	0	0	122,672	122,672
Freight transfer	0	0	0	124,936	124,936
Passenger transfer	0	0	0	175	175
Through passenger	0	0	0	63,527	63,527
Suburban passenger	0	0	0	36,045	36,045
Totals	0	0	0	661,342	661,342
Locomotive terminals	0	0	0	55,014	55,014
Totals	0	0	0	716,356	716,356
Steam Vessels:					
Tugs and lighters	12	0	234	8,579	8,825
River barges and dredges	0	0	82	1,132	1,214
Lake steamers and barges	0	0	0	954	954
Totals	12	0	316	10,665	10,993
High Pressure Steam Stationary Power and Heating Plants	0	423	14,824	1,815,830	1,831,077
Low Pressure Steam and other Stationary Heating Plants	193,511	13,896	40,543	244,214	492,164
Gas and Coke Plants:					
Public service	0	18,159	0	0	18,159
Other service	0	0	0	1,157	1,157
Totals	0	18,159	0	1,157	19,316
Furnaces:					
For metallurgical, manufacturing and other processes	633	303,973	362	251,489	556,457
Grand totals	194,156	336,451	56,045	3,039,711	3,626,363

TABLE LXXIV. COAL AND COKE CONSUMED DURING THE YEAR 1912 IN ZONES A AND B

Service	Tons of Fuel (2000 Lb.)				Total
	Anthracite	Coke	Pocahontas	Bituminous	
Steam Locomotives:					
Yard	0	0	23,049	1,340,454	1,363,503
Road freight	0	0	0	258,787	258,787
Freight transfer	0	0	2,996	476,742	479,738
Passenger transfer	0	0	885	20,660	21,545
Through passenger	0	0	2,441	237,847	240,288
Suburban passenger	0	0	0	191,372	191,372
Totals	0	0	29,371	2,525,862	2,555,233
Locomotive terminals	0	0	0	260,167	260,167
Totals	0	0	29,371	2,786,029	2,815,400
Steam Vessels:					
Tugs and lighters	124	0	3,982	39,872	43,978
River barges and dredges	0	0	1,268	10,471	11,739
Lake steamers and barges	0	0	0	36,651	36,651
Totals	124	0	5,250	86,994	92,368
High Pressure Steam Stationary Power and Heating Plants	5,291	2,544	277,020	8,862,479	9,147,334
Low Pressure Steam and other Stationary Heating Plants	1,771,272	55,077	889,728	1,930,833	4,646,910
Gas and Coke Plants:					
Public service	5,882	151,802	0	0	157,684
Other service	245	0	2,366	93,572	96,183
Totals	6,127	151,802	2,366	93,572	253,867
Furnaces:					
For metallurgical, manufacturing and other processes	44,344	3,226,330	27,052	955,281	4,253,007
Grand totals	1,827,158	3,435,753	1,230,787	14,715,188	21,208,886

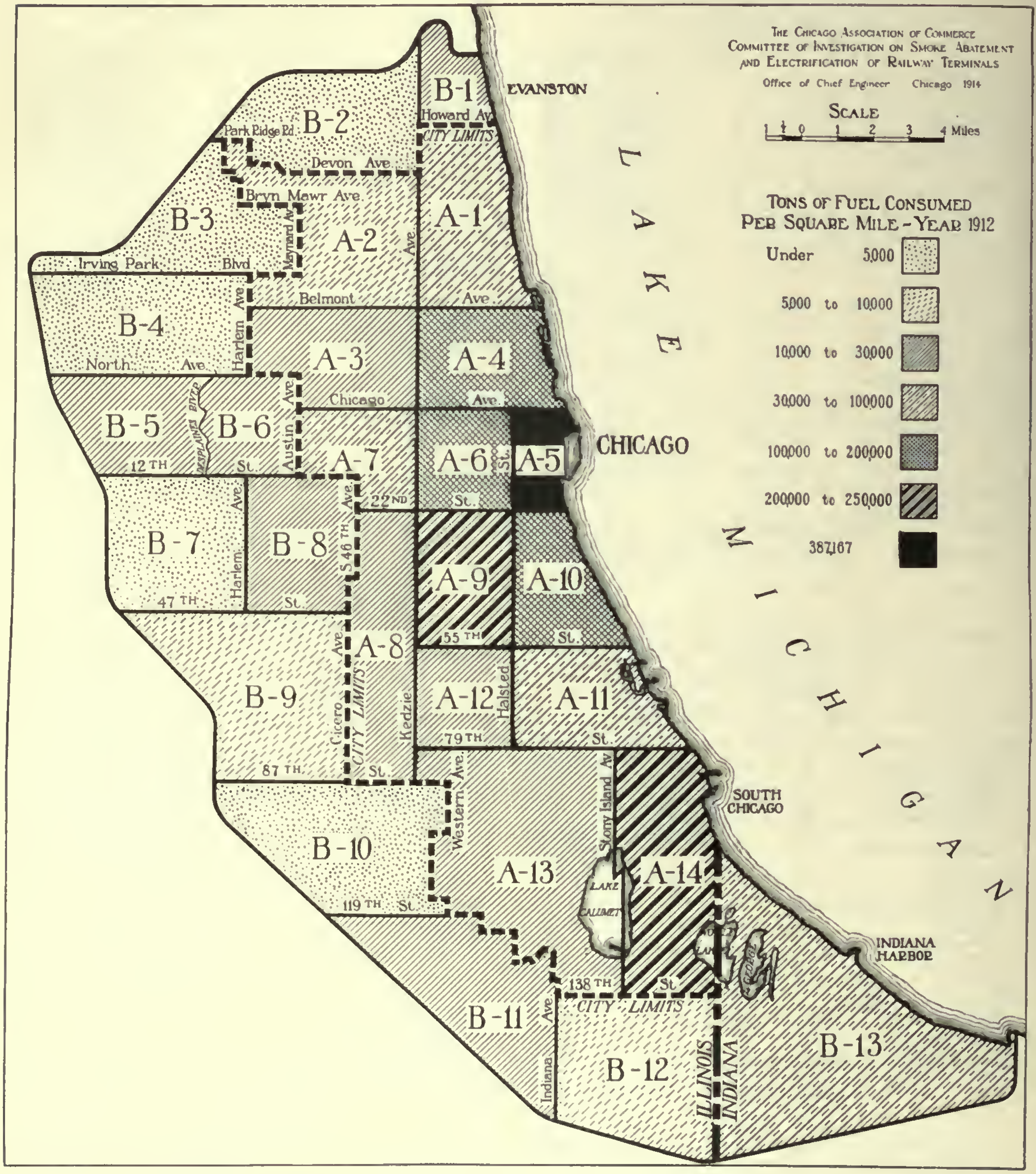


FIG. 14. RELATIVE DENSITY OF FUEL CONSUMPTION IN THE SEVERAL ZONE DISTRICTS

104.18 Consumption per Capita: The number of tons of fuel annually consumed per capita in each zone of the Area of Investigation is as follows:

	POPULATION (EST'D) FOR 1912	TONS
Zone A	2,285,000	7.7
Zone B	265,000	13.7
Zones A and B	2,550,000	8.3

104.19 Density of Consumption: The following table shows the average amount of fuel consumed annually, per square mile, by steam locomotives and by all other services in each zone of the Area of Investigation.

	TONS PER SQUARE MILE		
	ZONE A	ZONE B	A AND B
Steam locomotives	10,797	3,064	6,575
All other services	79,639	12,447	42,953
Totals	90,436	15,511	49,528

The quantities of fuel consumed per square mile in each of the zone districts and in the entire Area of Investigation are shown in table LXXV. The relative density of fuel consumption in the different districts is also represented graphically by fig. 14.

TABLE LXXV. DENSITY OF FUEL CONSUMPTION BY ZONE DISTRICTS

Zone District	Area Sq. Miles	Tons Consumed	Tons per Sq. Mile per Annum
A-1	16.08	615,404	38,271
A-2	18.26	120,464	6,597
A-3	13.50	299,268	22,168
A-4	12.16	2,141,965	176,148
A-5	4.52	1,749,995	387,167
A-6	9.00	1,387,024	154,114
A-7	8.75	562,651	64,303
A-8	15.50	172,678	11,141
A-9	12.00	2,951,027	245,919
A-10	9.58	1,413,813	147,580
A-11	12.36	778,071	62,951
A-12	9.00	137,132	15,237
A-13	33.55	717,217	21,378
A-14	20.16	4,535,814	224,991
Totals, Zone A	194.42	17,582,523	90,436
B-1	5.28	138,368	26,206
B-2	15.93	60,263	3,783
B-3	14.59	43,458	2,979
B-4	19.25	44,502	2,312
B-5	11.84	151,854	12,826
B-6	8.16	198,857	24,370
B-7	16.48	62,292	3,780
B-8	12.75	234,003	18,353
B-9	24.00	200,122	8,338
B-10	21.57	19,879	922
B-11	20.32	313,680	15,437
B-12	21.28	110,530	5,194
B-13	42.35	2,048,555	48,372
Totals, Zone B	233.80	3,626,363	15,511
Totals, Zones A and B	428.22	21,208,886	49,528

105. SMOKE*

SYNOPSIS: Smoke possesses a threefold character, to each aspect of which the Committee has applied suitable standards of measures. In its study of the visible properties of smoke, it has used the well known Ringelmann method; in its study of the solid constituents and of the gaseous products of smoke, it has had resort to means some of which have been initially devised by the Committee. The results presented show the extent to which the products of combustion arising from the consumption of fuel in Chicago contribute to the pollution of the city's atmosphere. The contributions of the different fuel consuming services are set forth in detail.

PROPERTIES OF SMOKE

105.01 Definition of Smoke: Public interest in smoke usually centers in its visibility. It has already been shown (chapter 101) that, in the enforcement of the smoke abatement ordinances of domestic and foreign cities, all inspections or investigations are based upon the appearance of the smoke. Legal prohibition in the case of certain cities applies to "dense smoke" or to "dense gray smoke," and in the case of other cities to "black, thick or continuous smoke." The limitations imposed by the acceptance of such a definition will at once be recognized, since the discharge from chimneys and smokestacks normally includes solid particles which may be so finely divided as to be invisible in the air, and it includes also invisible gases which must be received and dissipated by the atmosphere. A stack, therefore, does not cease to be a source of pollution when its discharge ceases to be dense or black. It is believed that, under certain conditions, the finely divided or invisible particles in the smoke constitute a more serious source of pollution than those properties which merely impart color or visibility to it.

The significance of these facts is emphasized by the results of the investigations herein described, and, in recognition of them, the term "smoke" as hereinafter used refers to the *gaseous and solid products of combustion, visible and invisible, including, in the case of certain industrial fires, mineral and other substances carried into the atmosphere with the products of combustion.*

According to this definition, smoke may be regarded as possessing a threefold character, to each aspect of which suitable standards of measure may be applied. These are as follows:

1. Visible properties.
2. Solid constituents.
3. Gaseous constituents.

In the sections which follow are set forth the results of a series of investigations showing the extent to which each of these properties of smoke affects the atmosphere of Chicago.

VISIBLE PROPERTIES OF SMOKE

105.02 Determination of Smoke Density: In the Committee's investigations in determining the relative density or visibility of smoke, the "Ringelmann Method" has been employed. This is the standard method commonly used by the departments of smoke inspection of domestic and foreign cities. The Ringelmann scale consists of six charts of equal size which may be drawn in black ink upon white paper or cardboard. The first chart is outlined only, its surface being entirely white. The sixth chart is filled in solid, its surface being entirely black. The intermediate charts are subdivided into small squares by crossed lines, the width of the line and the spacing being such as to darken a definite portion of the total area. The first chart (white) is designated as No. 0, or zero smoke. The second chart is subdivided by lines covering 20 per cent of its surface, and represents No. 1, or 20 per cent smoke. The third chart has heavier lines covering 40 per cent of its total surface, and represents No. 2, or 40 per cent smoke. The remaining charts represent respectively No. 3, or 60 per cent smoke, No. 4, or 80 per cent smoke, and No. 5 (black), or 100 per cent smoke. In working out the precise proportions, each of the intermediate charts is composed of squares ten millimeters from center to center of the lines bounding them, the thickness of the lines and

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* The original records from which this report is prepared are preserved in the Archives of the Committee, Vols. L 1 and L 2.

the white areas inclosed by them being as follows:

AREA	LENGTH OF SIDE OF WHITE SQUARE MILLIMETERS	WIDTH OF BLACK LINE MILLIMETERS	PER CENT OF AREA COVERED BY BLACK LINES
No. 0	Entire surface white	—	0
No. 1	8.94	1.06	20
No. 2	7.74	2.26	40
No. 3	6.32	3.68	60
No. 4	4.47	5.53	80
No. 5	Entire surface black	—	100

The Ringelmann scale is shown in fig. 15.

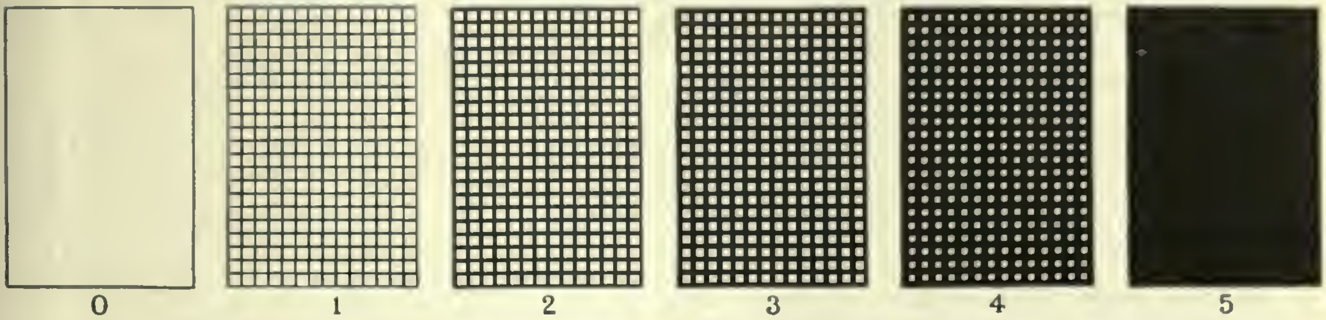

FIG. 15. RINGELMANN SCALE OF SMOKE DENSITIES (REDUCED)

The smoke under observation is compared directly with this scale, which is placed at a sufficient distance from the observer to cause the definition of the lines to be lost, the several intermediate areas presenting only varying shades of gray. The charts are placed preferably at a point between the observer and the stack under observation. An effort is made to obtain an unobstructed and clear background, and inspections requiring the observer to face or to look toward the sun are avoided wherever possible. If the smoke is invisible its density is given as zero. If, when compared with the scale, it matches area No. 1, its density is given as 20 per cent, if area No. 2, 40 per cent and so on. If the smoke discharged is black and matches area No. 5, its density is given as 100 per cent.

In computing the smoke density for a number of stacks or for those of an entire service or district, the observed results are reduced to unit values, the value of one stack for a period of one minute being termed a "stack minute" and the emission of No. 1 smoke for one minute, or its equivalent, being termed a "smoke unit." By employing these unit values, the per cent of density as measured by the Ringelmann scale may be computed by means of the following formula:

$$\text{Per cent of density} = \frac{\text{smoke units x 20}}{\text{stack minutes}}$$

In summarizing any number of observations, the total of all stack minutes may be used in the denominator and that of all smoke units in the numerator in this equation.

Special instruments designed for use in making observations of smoke are available. Such instruments usually consist of a telescope in which are placed a series of flat lenses of varying shades intended to correspond to the different shades of the Ringelmann scale. A lens of any desired shade may be adjusted so as to cover a portion of the field of vision. By observing the smoke through such a device and adjusting the instrument to bring into action the lens which matches the shade of the smoke, the density may be read from a scale on the instrument.

The fact should be emphasized that the Ringelmann scale and other devices designed for smoke observations are useful only to the extent of giving a numerical value to the shade or appearance of the smoke. The Ringelmann method does not take account of the volume of smoke discharged, nor of the amount or character of its solid and gaseous constituents. Smoke from a small stack may be as dense as that from a large stack, but the quantity of smoke delivered will, of course, be greater in the case of the large stack. The present discussion concerns smoke only from the standpoint of its visibility. Other properties of smoke are dealt with by other means which are hereinafter set forth.

In the development of the Committee's investigation with reference to the visible properties of smoke, a corps of from 16 to 20 trained smoke inspectors, under the supervision of a chief inspector, were engaged in making observations of smoke densities from April 22, 1912, to March 14, 1913. Their observations covered all classes of service and all portions of the Area of Investigation. The record includes the results of observations of smoke arising from 16,650 stacks and chimneys.

105.03 Density of Smoke from Steam Locomotives: Observations of smoke from locomotive smokestacks were made at each railroad yard, at each locomotive terminal and at various points along each line of railroad within the Area of Investigation. Inspectors were assigned each day to different locations, at which they observed and recorded the density of smoke arising from all locomotives coming under their observation. It was found that, in busy yards and at other points of heavy traffic, an experienced inspector could observe and record the performances of three or four different locomotives. In localities in which a large number of locomotives were operating at the same time, two or more inspectors were assigned to the work. Observations were made and recorded each minute during a predetermined period, readings being taken for clear stacks as well as for those emitting smoke. Every railroad yard and every section of running track in use within the Area of Investigation were inspected for a period of at least one day. The inspectors' observations were entered on a blank form, a reproduction of which is presented as fig. 16.

The inspectors in this service recorded the results of their observations by using the arbitrary numbers 0 to 5 assigned to the different charts of the Ringelmann scale and by entering in their reports the period of time covered by each observation.

The records show that 10,653 observations were made of smoke emissions from steam locomotives in railroad yards and at points on line of road, and that 1,323 observations were made of smoke emissions from locomotives at terminals, a total of 11,976 observations. The period of time required for an observation varied from one minute to an hour or more, depending upon the time during which the locomotive remained within the view of the observer. This large number of observations, when duly summarized, served to yield results which undoubtedly represent, with a high degree of accuracy, the performance of the entire locomotive service.

A summary of the results of all observations of locomotive smoke is presented as table LXXVI.

TABLE LXXVI. DENSITY OF STEAM LOCOMOTIVE SMOKE, AS DETERMINED BY THE RINGELMANN METHOD

Service	Number of Observations†	Stack Minutes		Smoke Units		Average Density of Smoke‡ Per Cent
		No.	Avg. per Stack	No.	Avg. per Stack	
1	2	3	4	5	6	7
Zone A*						
Yard.............	1,809	98,748	55	82,627	46	16.73¶
Road freight.......	610	4,181	7	5,293	9	25.32
Freight transfer....	2,504	21,977	9	24,346	10	22.16
Passenger transfer..	144	1,317	9	995	7	15.11
Through passenger .	1,721	9,992	6	10,037	6	20.09
Suburban passenger.	1,209	12,809	11	10,906	9	17.03
Totals.........	7,997	149,024	19	134,204	17	18.01
Loco. terminals.....	1,166	114,659	98	67,459	58	11.77
Totals.........	9,163	263,683	29	201,663	22	15.30
Zone B*						
Yard...	412	28,384	69	33,179	81	23.38
Road freight.......	494	4,097	8	5,512	11	26.91
Freight transfer....	888	9,093	10	12,074	14	26.56
Passenger transfer..	8	69	9	87	11	25.22
Through passenger..	606	3,730	6	4,919	8	26.38
Suburban passenger.	248	1,980	8	2,089	8	21.10
Totals..........	2,656	47,353	18	57,860	22	24.44
Loco. terminals.....	157	14,246	91	13,512	86	18.97
Totals..........	2,813	61,599	22	71,372	25	23.17
Totals — Zones A and B......	11,976	325,282	27	273,035	23	16.79

*Zone A is the city of Chicago, Zone B an area outside of the city included in the Committee's Area of Investigation.

†Observations were made from July 1, 1912, to November 23, 1912.

‡The "average density of smoke in per cent" is based upon the observed density or shade and the period of time involved by the observations. It does not take into consideration the amount of the solid or gaseous constituents of smoke, nor the volume of the smoke emissions.

¶The numerical values which are set forth in this chapter as measures of the amount of smoke discharged by different fuel consuming services, are carried out to the second decimal place as a matter of convenience in arranging and perpetuating the facts. It is not assumed that the degree of accuracy is such as justifies the retention of the fractional values.

105.04 The Density of Smoke from Steam Vessels: Smoke emissions from the stacks of steam vessels entering, leaving and operating within the Area of Investigation, were observed in the same manner as those from steam locomotive stacks. Observations were made of the density of smoke emitted from steam vessel smoke-stacks, while moving and at dock, along the 48.3 miles of navigable rivers and the 36.3 miles of lake shore. During the period from September 3, 1912, to September 17, 1912, 340 steam vessel smoke-stacks were observed. During the year, 5,751 steam vessels entered the ports of Chicago and of South Chicago from other lake ports, and 119 remained in the city and vicinity. These latter were not included in the number of entries. Records were kept on forms similar to that illustrated by fig. 16, and the results observed were summarized by applying the formula for density hereinbefore presented. The record of the results obtained from a total of 340 observations of smoke-stacks of steam vessels, as determined by the Ringelmann method, is presented as table LXXVII.

NOTES: Chicago & Western Indiana R. R.
78 th Street
Chicago

The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals

RECORD OF SMOKE OBSERVATIONS

AT 78 th Street, Aug. 7th 1912.

Weather Cloudy Temperature Deg.

BY Bennett Inspector

	8 AM	9 AM	9 AM	9 AM	9 AM	9 AM	9 AM	9 AM	9 AM	10 AM
	C. & O.	C.I. & L.	Belt	C.& W.I.	Erie	C.I. & L.	Belt	Belt	Belt	Erie
LOCO. NO.	1032	33	100	4	764	390	60	99	95	1781
TOTAL MINS.	1	2	2	2	1	1	15	2	3	2
TOTAL SMOKE UNITS	1	2	2	2	1	2	7	3	1	4

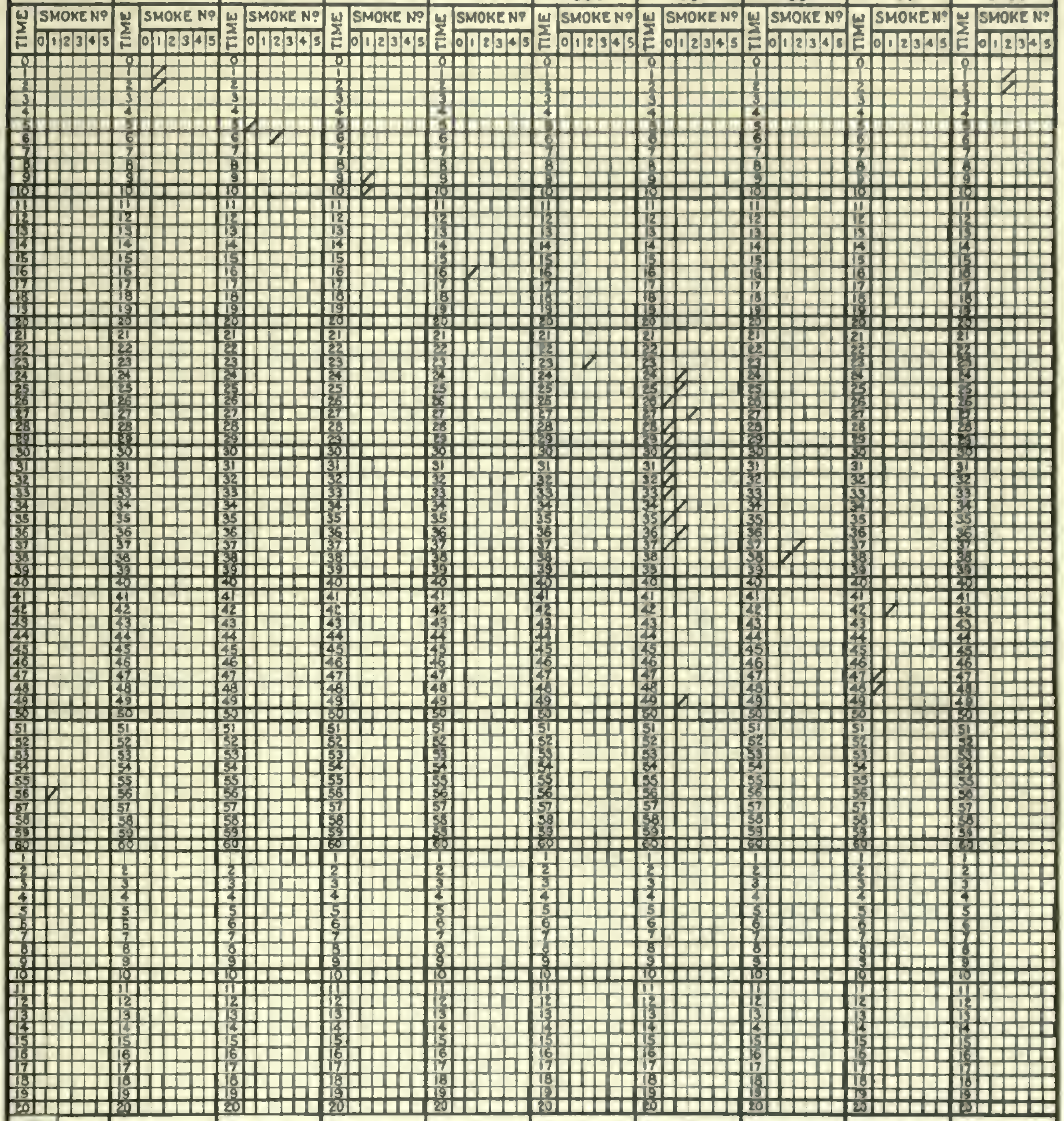

FIG. 16. TYPICAL SMOKE INSPECTOR'S REPORT
Showing smoke density for each observation, time of observation and the road and number of the locomotive observed. The Committee's office records indicated the class of service in which each locomotive was engaged.

TABLE LXXVII. DENSITY OF SMOKE FROM STEAM VESSELS, AS DETERMINED BY THE RINGELMANN METHOD

Service	Steamers Observed	Stacks Observed †		Stack Minutes		Smoke Units		Average Density of Smoke ‡ Per Cent
	No.	No.	Avg. per Stmr.	No.	Avg. per Stack	No.	Avg. per Stack	
1	2	3	4	5	6	7	8	9
Zone A *								
Tugs, lighters.	136	136	1.0	36,484	268	25,620	188	14.04¶
River barges, dredges, pile-drivers, etc. .	9	9	1.0	1,875	208	2.155	239	22.99
Lake steamers and barges. . .	178	181	1.0	42,113	233	31.135	172	14.79
Totals.	323	326	1.0	80,472	247	58,910	181	14.64
Zone B *								
Tugs, lighters.	3	3	1.0	1,030	343	1,263	421	24.52
River barges, dredges, pile-drivers, etc. .	9	9	1.0	4,140	460	5,994	666	28.96
Lake steamers and barges. . .	2	2	1.0	710	355	627	314	17.66
Totals	14	14	1.0	5,880	420	7,884	563	26.82
Totals—Zones A and B.	337	340	1.0	86,352	254	66,794	196	15.47

* Zone A is the city of Chicago, Zone B an area outside of the city included in the Committee's Area of Investigation.

† Observations were made from September 3, 1912, to September 17, 1912.

‡ The "average density of smoke in per cent" is based upon the observed density and the period of time involved by the observations. It does not take into consideration the amount of the solid or gaseous constituents of smoke, nor the volume of the smoke emissions.

¶ The numerical values which are set forth in this chapter as measures of the amount of smoke discharged by different fuel consuming services, are carried out to the second decimal place as a matter of convenience in arranging and perpetuating the facts. It is not assumed that the degree of accuracy is such as justifies the retention of the fractional values.

105.05 Density of Smoke from Chimneys and Stacks of Stationary Plants: Observations were made throughout the Area of Investigation to determine the density of smoke arising from chimneys and stacks serving all classes of stationary plants, including the following:

HIGH PRESSURE STEAM STATIONARY POWER AND HEATING PLANTS

1. Public service corporation plants (not including office buildings and hotels).
2. Municipal plants (not including office buildings and schools).
3. Steam railroad plants (not including office buildings).
4. Office buildings, hotels and schools.
5. Manufacturing plants.

LOW PRESSURE STEAM AND OTHER STATIONARY HEATING PLANTS

1. Large buildings and apartments of more than three flats (subject to city inspection).
2. Residences, small buildings and apartments of three flats or less (not subject to city inspection).

GAS AND COKE PLANTS

1. Public service (not including boiler power plants which were classed as high pressure steam stationary power and heating plants).
2. Other service (not including boiler power plants which were classed as high pressure steam stationary power and heating plants).

FURNACES FOR METALLURGICAL, MANUFACTURING AND OTHER PROCESSES

1. Steel plants, foundries, forges and allied processes.
2. Brick, pottery and allied processes.
3. Miscellaneous manufacturing, rendering and other processes.

The points at which the stacks observed are located are shown by the map presented as fig. 17.

In selecting stacks to be observed, it was sought to have them typical of all sizes and heights employed in the service they represented.

Observations were made by experienced smoke inspectors, and records in all cases were entered on forms similar to that illustrated by fig. 16. Observations covering an average period of 402 minutes per stack were made of 1,241 stacks serving 1,060 high pressure steam stationary power and heating plants.

Observations covering an average period of 401 minutes per stack were made of 2,801 stacks serving 2,801 low pressure steam and other stationary heating plants. In determining the density of smoke from domestic fires, the number of observations made was regulated by the distribution of population, one observation, wherever possible, being made for each thousand inhabitants. In districts where the population was less than 1,000 per square mile, at least 4 chimneys per square mile were observed, providing there were as many within the vision of a single inspector. Observations of stacks serving low pressure steam and other stationary heating plants were made throughout the entire Area of Investigation.

Observations covering an average period of 465 minutes per stack were made of 12 stacks serving 6 gas and coke plants.

Observations covering an average of 377 minutes per stack were made of 280 stacks serving 80 plants for metallurgical, manufacturing and other processes.

The observations of stacks of stationary plants embraced a total of 4,334 different chimneys and stacks serving 3,947 individual plants. A record of the density of smoke arising from stationary smoke-stacks and chimneys, as determined by the Ringelmann method, is presented as table LXXVIII, in which are set forth for each service the detailed record of all factors entering into the determination of densities.

FIG. 17. LOCATION OF OBSERVED CHIMNEYS AND STACKS OF STATIONARY PLANTS IN THE AREA OF INVESTIGATION

TABLE LXXVIII. DENSITY OF SMOKE FROM STATIONARY PLANTS, AS DETERMINED BY THE RINGELMANN METHOD

Service	Plants Observed	Stacks Observed†		Stack Minutes		Smoke Units		Average Density of Smoke‡ Per Cent
	No.	No.	Avg. per Plant	No.	Avg. per Stk.	No.	Avg. per Stk.	
1	2	3	4	5	6	7	8	9
High Pressure Steam Stationary Power and Heating Plants								
Zone A *								
Public service corporation plants (excluding office buildings and hotels)	27	51	1.9	21,976	431	10,265	201	9.34¶
Municipal plants (excluding office buildings and schools)	30	35	1.2	13,818	395	5,737	164	8.30
Steam railroad plants (excluding office buildings)	28	41	1.5	16,009	390	9,043	221	11.30
Office and storage buildings, hotels, schools, etc.....	254	259	1.0	106,465	411	39,833	154	7.48
Manufacturing plants.........	604	700	1.2	280,752	401	163,884	234	11.67
Totals.........	943	1,086	1.2	439,020	404	228,762	211	10.42
Zone B								
Public service corporation plants (excluding office buildings and hotels)	14	20	1.4	7,800	390	7,428	371	19.05
Municipal plants (excluding office buildings and schools)	9	9	1.0	3,607	401	3,158	351	17.51
Steam railroad plants (excluding office buildings)	8	8	1.0	3,065	383	2,628	329	17.15
Office and storage buildings, hotels, schools, etc.....	1	1	1.0	285	285	124	124	8.70
Manufacturing plants	85	117	1.4	44,708	382	65,630	561	29.36
Totals.........	117	155	1.3	59,465	384	78,968	509	26.56
Total–Zones A & B	1,060	1,241	1.2	498,485	402	307,730	248	12.35
Low Pressure Steam and Other Stationary Heating Plants								
Zone A								
Large buildings and apartments of more than three flats	539	539	1.0	209,662	389	30,792	57	2.94
Residences, small buildings and apartments of 3 flats and less...	1,979	1,979	1.0	810,690	410	51,940	26	1.28
Totals.........	2,518	2,518	1.0	1,020,352	405	82,732	33	1.62
Zone B								
Large buildings and apartments of more than three flats	11	11	1.0	3,960	360	567	52	2.86
Residences, small buildings and apartments of three flats and less	272	272	1.0	99,684	366	4,131	15	0.88
Totals.........	283	283	1.0	103,644	366	4,698	17	0.91
Totals–Zones A & B	2,801	2,801	1.0	1,123,996	401	87,430	31	1.56

*Zone A is the city of Chicago, Zone B an area outside of the city included in the Committee's Area of Investigation.

†Observations were made from April 22, 1912, to March 14, 1913.

‡The "average density of smoke in per cent" is based upon the observed density or shade and the period of time involved by the observations. It does not take into consideration the amount of the solid or gaseous constituents of smoke, nor the volume of the smoke emissions.

¶The numerical values which are set forth in this chapter as measures of the amount of smoke discharged by different fuel consuming services, are carried out to the second decimal place as a matter of convenience in arranging and perpetuating the facts. It is not assumed that the degree of accuracy is such as justifies the retention of the fractional values.

TABLE LXXVIII (Continued). DENSITY OF SMOKE FROM STATIONARY PLANTS, AS DETERMINED BY THE RINGELMANN METHOD

Service	Plants Observed	Stacks Observed†		Stack Minutes		Smoke Units		Average Density of Smoke‡ Per Cent
	No.	No.	Avg. per Plant	No.	Avg. per Stk.	No.	Avg. per Stk.	
1	2	3	4	5	6	7	8	9
Gas and Coke Plants								
Zone A *								
Public service (excluding boiler power plants)...	3	6	2.0	2,700	450	0	0	0¶
Other service (excluding boiler power plants)..	1	2	2.0	1,080	540	145	73	2.69
Totals........	4	8	2.0	3,780	473	145	18	0.77
Zone B								
Public service (excluding boiler power plants)..	2	4	2.0	1,800	450	0	0	0
Other service (excluding boiler power plants)...	0	0	0	0	0	0	0	0
Totals........	2	4	2.0	1,800	450	0	0	0
Totals–Zones A & B	6	12	2.0	5,580	465	145	12	0.52
Special Furnaces for Metallurgical, Manufacturing and Other Processes								
Zone A								
Steel plants, foundries, forges and other allied processes (excluding boiler power plants).........	38	149	3.9	55,954	376	39,242	263	14.03
Brick, pottery and other allied processes (excluding boiler power plants)	2	7	3.5	2,893	413	1,717	245	11.87
Miscellaneous manufacturing, rendering and other processes.	9	18	2.0	7,045	391	2,748	153	7.80
Totals........	49	174	3.6	65,892	379	43,707	251	13.27
Zone B								
Steel plants, foundries, forges and other allied processes (excluding boiler power-plants).........	23	67	2.9	24,348	363	26,766	399	21.99
Brick, pottery and other allied processes (excluding boiler power plants).........	7	38	5.4	14,827	390	22,555	594	30.42
Miscellaneous manufacturing, rendering and other processes.	1	1	1.0	450	450	189	189	8.40
Totals........	31	106	3.5	39,625	374	49,510	467	24.99
Totals–Zones A & B	80	280	3.5	105,517	377	93,217	333	17.67

*Zone A is the city of Chicago, Zone B an area outside of the city included in the Committee's Area of Investigation.

†Observations were made from April 22, 1912, to March 14, 1913.

‡The "average density of smoke in per cent" is based upon the observed density or shade and the period of time involved by the observations. It does not take into consideration the amount of the solid or gaseous constituents of smoke, nor the volume of the smoke emissions.

¶The numerical values which are set forth in this chapter as measures of the amount of smoke discharged by different fuel consuming services, are carried out to the second decimal place as a matter of convenience in arranging and perpetuating the facts. It is not assumed that the degree of accuracy is such as justifies the retention of the fractional values.

105.06 Relative Importance of the Different Services as Producers of Visible Smoke: From a knowledge of the amount of fuel consumed in different classes of service (chapter 104) and of the average density of smoke arising from each of these services, as set forth in sections 105.01 to 105.05, inclusive, an estimate was made of the relative importance of the different services as producers of visible smoke. Thus, the total tons of fuel consumed in each service multiplied by the average smoke density for that service yields a product which is proportional to the total amount of visible smoke produced by the service, and the ratio of the product thus obtained to the sum of such products for all services gives a measure of the relative amount of visible smoke produced by the service in question as compared with the total visible smoke for all services. The results of this process repeated for each of the different services are presented, for Zone A as table LXXIX, for Zone B as table LXXX and for Zones A and B combined as table LXXXI.

TABLE LXXIX. RELATIVE AMOUNT OF VISIBLE SMOKE PRODUCED BY EACH SERVICE, AS DETERMINED BY THE RINGELMANN METHOD

ZONE A

(City of Chicago)

Service	Fuel Consumed Tons	Average Smoke Density Per Cent	Relative Standing Per Cent
Steam Locomotives:			
Yard	1,049,516	16.73	10.25
Road freight	136,115	25.32	2.01
Freight transfer	354,802	22.16	4.59
Passenger transfer	21,370	15.11	0.19
Through passenger	176,761	20.09	2.07
Suburban passenger	155,327	17.03	1.54
Locomotive terminals	205,153	11.77	1.41
Totals	2,099,044	.....	22.06
Steam Vessels:			
Tugs and lighters	35,153	14.04	0.29
River barges, dredges, pile-drivers, etc.	10,525	22.99	0.14
Lake steamers and barges	35,697	14.79	0.31
Totals	81,375	.....	0.74
High Pressure Steam Stationary Power and Heating Plants, including:			
Public service corporation plants	7,316,257	10.42	44.49
Municipal plants			
Steam railroad plants			
Office buildings, hotels and schools			
Manufacturing plants			
Low Pressure Steam and Other Stationary Heating Plants, including:			
Large and small buildings	4,154,746	1.62	3.93
Large and small apartments			
Residences			
Gas and Coke Plants:			
Public service (not including boiler power plants)	139,525	0.00	0.00
Other service (not including boiler power plants)	95,026	2.69	0.15
Totals	234,551	.....	0.15
Furnaces for Metallurgical, Manufacturing and Other Processes, including:			
Steel plants, foundries, forges, and allied processes (not including boiler power plants)	3,696,550	13.27	28.63
Brick, pottery and allied processes (not including boiler power plants)			
Miscellaneous manufacturing, rendering and other processes			
Grand Totals	17,582,523	.....	100.00

The relative importance of the several services as producers of visible smoke is shown graphically by the diagrams presented as fig. 18.

CONDITIONS PROMOTING VISIBLE SMOKE

105.07 Information Concerning Furnace Conditions: The Committee's purpose in the work described in the sections immediately preceding has been that of determining the relative importance of various sources of visible smoke.

TABLE LXXX. RELATIVE AMOUNT OF VISIBLE SMOKE PRODUCED BY EACH SERVICE, AS DETERMINED BY THE RINGELMANN METHOD

ZONE B

(Outlying Territory Included in the Area of Investigation)

Service	Fuel Consumed Tons	Average Smoke Density Per Cent	Relative Standing Per Cent
Steam Locomotives:			
Yard	313,987	23.38	9.09
Road freight	122,672	26.91	4.09
Freight transfer	124,936	26.56	4.11
Passenger transfer	175	25.22	0.01
Through passenger	63,527	26.38	2.08
Suburban passenger	36,045	21.10	0.94
Locomotive terminals	55,014	18.97	1.29
Totals	716,356	.....	21.61
Steam Vessels:			
Tugs and lighters	8,825	24.52	0.27
River barges, dredges, pile-drivers, etc.	1,214	28.96	0.04
Lake steamers and barges	954	17.66	0.02
Totals	10,993	.....	0.33
High Pressure Steam Stationary Power and Heating Plants, including:			
Public service corporation plants	1,831,077	26.56	60.24
Municipal plants			
Steam railroad plants			
Office buildings, hotels and schools			
Manufacturing plants			
Low Pressure Steam and Other Stationary Heating Plants, including:			
Large and small buildings	492,164	0.91	0.59
Large and small apartments			
Residences			
Gas and Coke Plants:			
Public service (not including boiler power plants)	18,159	0.00	0.00
Other service (not including boiler power plants)	1,157	0.00	0.00
Totals	19,316	0.00	0.00
Furnaces for Metallurgical, Manufacturing and Other Processes, including:			
Steel plants, foundries, forges, and allied processes (not including boiler power plants)	556,457	24.99	17.23
Brick, pottery and allied processes (not including boiler power plants)			
Miscellaneous manufacturing, rendering and other processes			
Grand Totals	3,626,363	.....	100.00

This purpose having been accomplished, it will be of interest to consider the causes of visible smoke as they are to be found in conditions existing in the furnace and the relation between visible smoke and furnace conditions.

The Committee's records of inspection, which include results from observations of several thousand stacks and chimneys, are not paralleled by observations covering the furnace conditions giving rise to these discharges. It is therefore not possible to draw from this voluminous record any conclusions concerning the relation between visible smoke and furnace conditions. A knowledge, however, of present practice as set forth in existing literature, and the fact that the Committee's records present more than 100 tests for which certain facts concerning furnace conditions, as well as those relating to smoke, were observed and recorded, will justify the discussion and the conclusions which are set forth in the sections which follow.

TABLE LXXXI. RELATIVE AMOUNT OF VISIBLE SMOKE PRODUCED BY EACH SERVICE, AS DETERMINED BY THE RINGELMANN METHOD

ZONES A and B
(Entire Area of Investigation)

Service	Fuel Consumed Tons	Average Smoke Density Per Cent	Relative Standing Per Cent
Steam Locomotives:			
Yard	1,363,503	18.22	9.85*
Road freight	258,787	26.11	2.68
Freight transfer	479,738	23.44	4.46
Passenger transfer	21,545	15.61	0.13
Through passenger	240,288	21.80	2.08
Suburban passenger	191,372	17.57	1.33
Locomotive terminals	260,167	12.56	1.30
Totals	2,815,400	.....	21.83
Steam Vessels:			
Tugs and lighters	43,978	15.05	0.26
River barges, dredges, pile-drivers, etc.	11,739	27.25	0.13
Lake steamers and barges	36,651	14.83	0.22
Totals	92,368	.....	0.61
High Pressure Steam Stationary Power and Heating Plants, including:			
Public service corporation plants	9,147,334	12.35	44.79
Municipal plants			
Steam railroad plants			
Office buildings, hotels and schools			
Manufacturing plants			
Low Pressure Steam and Other Stationary Heating Plants, including:			
Large and small buildings	4,646,910	1.56	2.87
Large and small apartments			
Residences			
Gas and Coke Plants:			
Public service (not including boiler power plants)	157,684	0.00	0.00
Other service (not including boiler power plants)	96,183	2.69	0.10
Totals	253,867	.....	0.10
Furnaces for Metallurgical, Manufacturing and Other Processes, including:			
Steel plants, foundries, forges and allied processes (not including boiler power plants)	4,253,007	17.67	29.80
Brick, pottery and allied processes (not including boiler power plants)			
Miscellaneous manufacturing, rendering and other processes			
Grand Totals	21,208,886	.....	100.00

* The numerical values, which are set forth in this chapter as measures of the amount of smoke discharged by different fuel consuming services, are carried out to the second decimal place as a matter of convenience in arranging and perpetuating the facts. It is not assumed that the degree of accuracy is such as justifies the retention of the fractional values.

105.08 Furnace Conditions and Visible Smoke: Visible smoke arising from the burning of bituminous fuels is the result of a failure, either in the design of the furnace or in its operation, to observe certain conditions which are the necessary accompaniments of so-called "smokeless" combustion. These conditions have already been set forth (section 101.28). They may be summarized briefly as follows:

> 1. The coal must be introduced into the furnace at such a point and distributed in such a way that the gases distilled from it will be required to pass over or through the incandescent portions of the fire. The observance of this condition will, in most cases, expose the distillates to a temperature sufficiently high to insure their ignition. These distillates, if not burned, are prolific sources of visible smoke.
>
> 2. The stream of gases from the fuel must be heated quickly and kept at a high temperature until the process of combustion is well advanced. The presence of a fire-brick arch under which the distillates may be burned, and the passing of the distillates through the bed of fire, are aids in securing this condition.
>
> 3. The interposition of heat absorbing surfaces in close proximity to the burning distillates tends to cool the gases, to suppress combustion and to produce visible smoke.
>
> 4. The admission of air, by which combustion is stimulated, should be provided for at proper points and should be carefully regulated.
>
> 5. The proportions of the furnace should be such as will provide an ample flameway or combustion chamber. The observance of this condition is necessary in order that the time occupied by the gases in passing through the furnace may be sufficient to permit them to burn completely.

If all of these conditions are observed, the smoke arising from fires of bituminous coal will be nearly if not wholly invisible, but there are many practical difficulties to be met by one who seeks to observe them; as a consequence, the products of combustion issuing from bituminous coal fires are commonly more or less visible, depending upon the degree of success in securing the conditions which have been specified.

105.09 The Flameway in its Relation to Visible Smoke: Fuels burn with different lengths of flame, depending upon their composition. For example, coke and anthracite coal, the principal combustible element of which is carbon, burn with a very short flame. The whole process of combustion takes place at or near the surface of the fuel. Such fuels can be burned without developing visible smoke even though the flameway may be extremely short and otherwise restricted.

The bituminous coals of Pennsylvania and Ohio are relatively lower in carbon and higher in volatile matter than coke or anthracite coal and the volume of gases distilled from bituminous coals, freshly applied to the fire, is much greater. The process of intermixing and combining the combustible gases thus distilled with the air necessary to their combustion also takes an appreciable period of time; hence the flame is comparatively long and the furnace must be such as to supply room in which combustion may proceed. A furnace which fails to supply the necessary space permits the unconsumed gases to pass through to the stack, and visible smoke results.

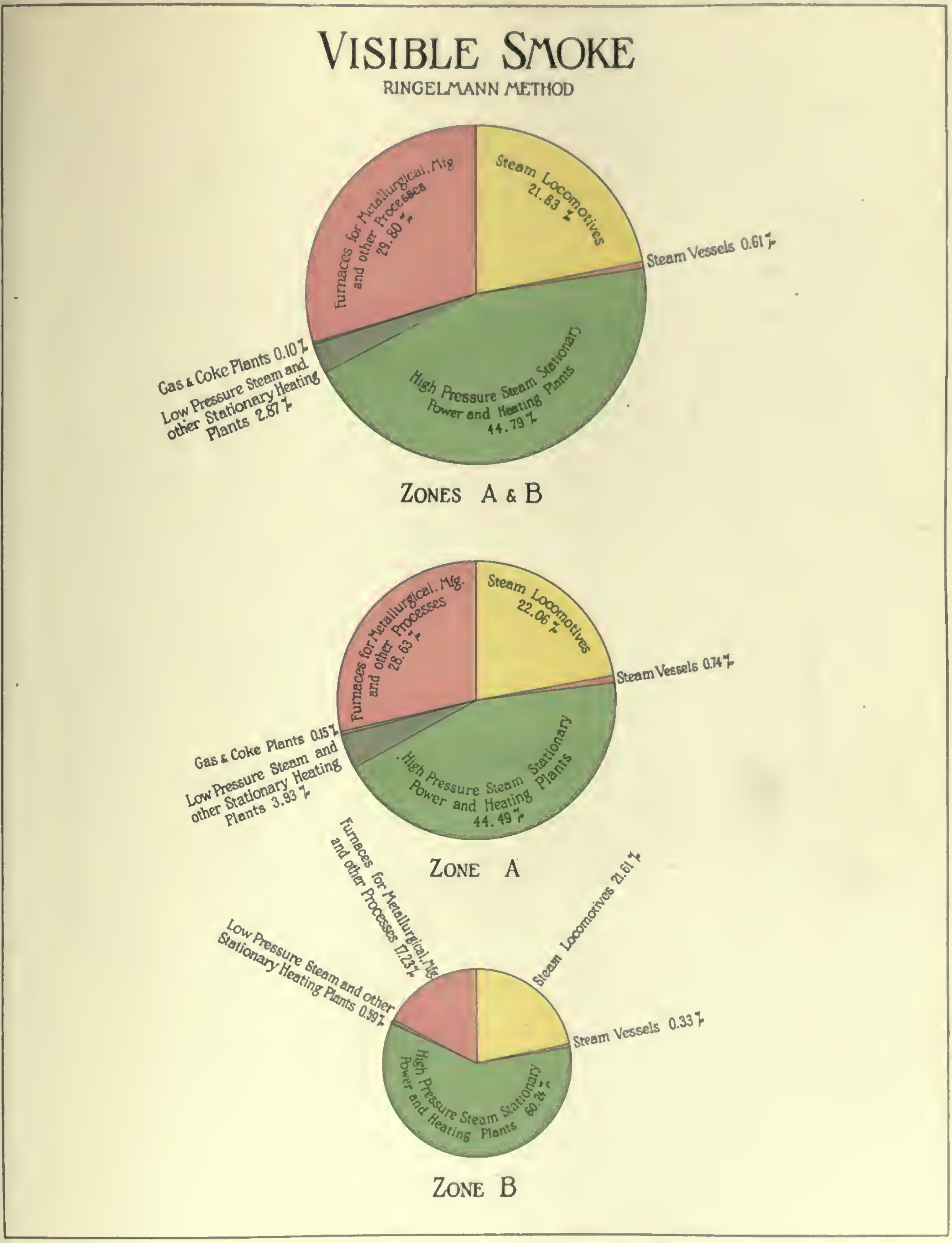

FIG. 18. RELATIVE IMPORTANCE OF THE SEVERAL CLASSES OF SERVICE AS PRODUCERS OF VISIBLE SMOKE

The bituminous coals of Illinois are higher in volatile matter than are the bituminous coals of Pennsylvania and Ohio, hence they require a still longer flameway. There is frequent failure, in the construction of furnaces, to observe the condition thus imposed. Furnace construction which has proved satisfactory for the use of bituminous coals from Pennsylvania is too often thought to be satisfactory for Indiana and Illinois coals, and the result is often the production of unnecessary visible smoke. Wherever Illinois and Indiana coals are to be burned, a long flameway is a first essential.

It will at once be apparent that, while it is possible to provide a sufficient length of flameway for large fires, such as those serving boilers of considerable size, the problem is more difficult when applied to small fires. The ordinary domestic stove, for example, so long as present lines of construction are adhered to, cannot well be made sufficiently large to supply the necessary space. Small heating furnaces and furnaces of small boilers also present disadvantageous conditions which are not ordinarily overcome.

105.10 The Temperature of the Flameway in its Relation to Visible Smoke: The burning of Illinois and Indiana bituminous coal in fires of low temperature results in the production of visible smoke. It is because of these low temperatures that fires of stoves and small furnaces, receiving attention at infrequent intervals, are sometimes prolific sources of visible smoke. A large mass of fresh Illinois coal placed upon the surface of a fire at once lowers the furnace temperature to such a degree that the distillates which come from the fresh coal pass off without igniting.

A solution of the problem of maintaining a constant high temperature in the fire-box, which is one essential condition to smokeless combustion, is promoted by the use of brick arches bounding a portion of the flameway. Where the furnace is so constructed that initial combustion takes place under a fire-brick arch, the arch serves to conserve the heat and to maintain, at a point where it is most needed, a temperature sufficiently high to ignite the distilled gases. The brick arch under which the fuel may be progressively introduced into the furnace may be applied to large furnaces with comparative ease, but its application to furnaces for smaller fires is much more difficult.

In the absence of a brick arch, the heat of the fire is likely to be so dissipated that its temperature will fall below that necessary to yield best results; this unfavorable condition is enhanced when the furnace is small and, in the case of boiler fires, when the heating surface of the boiler is made to approach too near the grate. The whole furnace design should be such as will serve to maintain a high temperature throughout the length of the flameway, after which the gases may be permitted to come in contact with heat absorbing surfaces.

Results taken from the records of the Committee, covering both stoker and hand fired furnaces of many different kinds, with and without brick arches, some of which were designed to promote the mixing of gases as well as to maintain furnace temperatures, may be summarized as follows:

	NUMBER OF OBSERVATIONS	AVERAGE DENSITY OF VISIBLE SMOKE
With brick arches	561	13.16
Without brick arches . . .	200	16.73

The reduction in visible smoke resulting from the presence of an arch, as disclosed by this comparison covering many different furnaces, amounts to 3.57 per cent on the Ringelmann scale. This value is not put forth as a measure of the benefit to be expected from the use of the arch as it might be disclosed by tests strictly comparative, but as evidence drawn from many sources, not all of which are comparable, disclosing a tendency which is pronounced. The brick arches mentioned were generally in the path of the gases as mixing devices rather than above the fire as ignition devices.

The brick arch is not the only means employed to insure high temperatures to which the distillates of the freshly fired coal may be exposed. The so-called underfeed furnaces are so designed as to permit a strong concentration of draft under conditions which localize combustion in such a way that high temperatures are assured at points where the distillates are liberated. The "down-draft" type of furnace is designed and operated in such a way that distillates of the fuel are drawn through the firebed, and extend themselves into a flameway of fire both above and below. All arrangements such as these, which effectively provide for an initial flameway of high temperature, supply one of the important elements essential to the elimination of visible smoke from furnaces in which bituminous coal is used.

105.11 **Draft in its Relation to Visible Smoke:** Furnace draft is the governor controlling the rate of combustion. If the draft is weak, the rate of combustion will be low and the temperature of the fire may be lower than that which is necessary for the suppression of visible smoke. If the draft is strong, the rate of combustion becomes high and the temperature of the fire is raised. Even though other conditions are unfavorable, the high temperature of the fire will do much to promote smokeless combustion.

The draft action stimulates the movement of a current of air through the bed of coal and supplies the oxygen which, in combining with the carbon and hydrocarbons of the fuel, causes combustion. It is evident that, other things being equal, a relatively strong draft will distribute itself through the bed of fuel more uniformly than a draft which is weak. A strong draft also stimulates the activity of the intermixing currents in the furnace and so aids combustion. Strong drafts normally imply high rates of combustion and high furnace temperatures, so that, in general, it may be said that the abatement of visible smoke is promoted by increasing the draft of the furnace. Here again the solution of the problem is comparatively easy in its application to large fires and extremely difficult in its application to small fires. Unless mechanical means are employed to stimulate it, the draft is a function of the height of the chimney. A great power plant may profitably be equipped with a lofty chimney to insure satisfactory draft conditions, but a private dwelling house or a small industrial plant must accept chimneys of less height.

105.12 **Rates of Combustion in their Relation to Visible Smoke:** The rate of combustion depends upon the draft and hence, as affecting furnace action, the terms "draft" and "rates of combustion" are almost synonymous. Nevertheless, it is of interest to center the attention on the process which goes on at the grate. The burning of less than five pounds of coal per square foot of grate surface per hour is normally to be regarded as a low rate of combustion. With natural draft and comparatively low chimneys this rate may be more than doubled and, with very lofty chimneys or by mechanical means, it may be many times multiplied. A high rate of combustion, as already indicated, implies high furnace temperatures, and these, in combination with a sufficient flameway, tend to reduce the visible smoke.

105.13 **Excess Air in its Relation to Visible Smoke:** Perfect combustion implies that all of the carbon in the fuel shall have an opportunity to combine with oxygen. The oxygen needed for this purpose is supplied by the air which is borne into the furnace by the action of the draft. If the supply of air is deficient, the burning process will be incomplete and visible smoke will result. To avoid such an occurrence, it is customary to provide for a larger supply of air than is needed to support combustion and, under some conditions, the excess supply is very large. The significance of this statement is more fully discussed elsewhere (section 101.04). It need only be noted in this connection that an excessive supply of air tends to lower the temperature of the fire, to cool the flameway and, under certain conditions, to increase the visible smoke. Up to a certain limit, however, which may vary with the construction of the furnace, increasing the air supply aids in reducing the visible smoke.

105.14 **Automatic Stoking in its Relation to Visible Smoke:** No one thing has been more potent in contributing to the elimination of visible smoke than the advent of mechanical stokers and other forms of automatic furnaces. These devices represent results achieved in the development of furnace design to meet the requirements of theoretical conditions. Their introduction implies not only automatic feeding, but the acceptance of other conditions essential in the elimination of visible smoke. Mechanical stokers provide for the progressive movement of the fuel into the furnace; they generally provide for an ample flameway and a brick arch under which the initial combustion may proceed. They are rarely installed except where satisfactory draft conditions are assured; as a consequence, it is commonly assumed that the mechanical stoker or hopper-fed furnace is a smoke abating device, and in general this assumption is justified. This statement does not imply that mechanical stokers, or other devices for automatic stoking, will in themselves suffice to make smoke invisible. It is only when they are properly operated that they can be depended upon to give satisfactory results. If a stoker is worked beyond its capacity, or if carelessly or improperly manipulated, the visible smoke discharged from it will increase. The Committee's records present many examples in which the smoke from stoker-fired furnaces is as dense as that from hand-fired furnaces. It will be understood, also, that the preceding statements refer specifically to visible smoke; it will hereafter be shown that the solid constituents of smoke are not greatly affected by the use of automatic stoking devices.

105.15 Care in Firing in its Relation to Visible Smoke: The investigations of the Committee are impressive in the testimony they yield as to the value of care in firing as a means of reducing visible smoke. This statement applies whatever may be the form of furnace used or apparatus employed. Careless hand-firing results in large volumes of visible smoke; careful, frequent and progressive hand-firing results in the elimination of most of this smoke. The careless manipulation of the automatic stoker may result in the production of visible smoke; its careful handling will suffice to eliminate most of this smoke. The results of the Committee's investigation touching this point disclose convincing evidence of this fact. A comparison of the smoke arising from any coal consuming service, as maintained within the city limits of Chicago where its operation is subject to municipal inspection, with that arising from the same class of service outside the city where no restrictions are imposed, will disclose a lower density of smoke within the city than outside. That is, where it is necessary to reduce the visible smoke, the attention needed to secure such a result is given; where it is not necessary, the effect of neglect is to be seen in the result.

105.16 The Size of the Fire in its Relation to Visible Smoke: The fact has already been pointed out that large fires can more readily be maintained under conditions favorable to the elimination of visible smoke than small fires. The purposes to which large fires are applied normally assure room in which to develop suitable furnace dimensions; the importance of the fire justifies the adoption of means which will afford satisfactory flameway, temperature and draft conditions, and the cost of added equipment is relatively not significant. These conditions are all reversed when applied to small fires. It is for this reason that the real problem in controlling the output of visible smoke centers in small fires. Visible smoke, as an attendant of large fires, has already received initial attention in Chicago, and the way is open and well understood by skilled firemen, by which the smoke from all such fires may readily be made nearly if not quite invisible.

105.17 Selection of Fuel in its Relation to Visible Smoke: Different fuels when burned under identical conditions give results which are entirely unlike. Fuels high in carbon and low in volatile matter, such as coke or anthracite coal, may be burned in very simple furnaces of limited dimensions without danger of producing visible smoke. Fuels which are low in carbon and relatively high in volatile matter cannot be successfully burned in furnaces which may be entirely satisfactory for the high carbon fuels. The reason has been made apparent in the course of the discussions already presented. The conclusion seems to be that each kind of coal should have a furnace designed to suit its peculiar requirements.

In view of these facts it often happens that, where fuel is being burned in furnaces not suited to its requirements, and where objection is raised to the visible smoke which results, the owner may prefer to change the character of fuel rather than to change the construction of his furnace; that is, for the purpose of reducing visible smoke, it is sometimes easier to select a fuel adapted to the requirements of the furnace than to construct a furnace adapted to the requirements of the fuel. The fact must, of course, be recognized that there are limits in the choice of fuel. In the long run each consumer must use that fuel which is naturally tributary to his plant and ultimately he will make his furnace conform to the requirements of that fuel.

105.18 Furnace Efficiency in its Relation to Visible Smoke: It is often assumed that the elements promoting visibility in smoke represent heat values of considerable significance, and that the abatement of visible smoke must in all cases result in large economy through the reduction of waste. Such a conception is not sustained by the facts. The heat value of the visible constituents of smoke is so small that measures taken to reduce visible smoke may often tend to lower the furnace efficiency rather than to increase it. For example, the furnace designer who seeks to equip a comparatively small furnace with those devices which will permit it to burn Illinois coal without visible smoke, may discover that in the enlargement of his furnace he has permitted some increase in radiation or some increased loss through air leakages which, while incidental, may equal or exceed the gains resulting from the elimination of visible smoke. Again, the operator who seeks to improve stack conditions by increasing his air supply may find that the cooling effects of the added air may more than offset any economic gain which might otherwise accrue from the suppression of visible smoke. The fact to be emphasized is that, other things being equal, the difference in the amount of heat which may be dissipated by visible smoke, as compared with that which may be dissipated by smoke from the same stack which is invisible, is extremely small.

The elements promoting visibility in smoke cannot be completely defined. It is known, however, that solid particles combined with moisture are important factors. The amount of heat represented by the solids discharged in visible smoke, as compared with that in the solids discharged in smoke of low visibility, is set forth as table LXXXII.

TABLE LXXXII. HEAT VALUE OF THE SOLIDS IN VISIBLE SMOKE

Test Number	Smoke Density Per Cent	Heat Value of the Solids in Visible Smoke Expressed in Per Cent of the Heat Value of the Fuel Fired
1—Fires with High Smoke Density		
3	21.97	0.28
17	20.00	0.36
10	20.00	0.95
30	15.80	0.49
29	14.50	0.49
Average	18.45	0.51
2—Fires with Low Smoke Density		
56	0	0.21
57	0	0.08
80	0	0.74
81	0	0.48
85	0	0.11
Average	0	0.32

The two groups of tests, the results of which are presented in table LXXXII, show high and low results respectively, on the basis of visibility. It will be seen that the portion of the heat of the fuel represented by the solids of smoky stacks is greater than that represented by the solids of stacks which are not smoky, by an amount equal to 0.2 per cent of the heat value of the fuel. All results are from high pressure boiler furnaces. The average heat loss in the visible properties of smoke from 19 different tests of boiler furnaces was found to be 0.4 per cent of the heat value of the fuel fired.

105.19 Smoke Abatement as an Indirect Means of Effecting Economy: While the constituents of smoke which impart visibility to it represent a relatively small amount of heat and while, as a consequence, no great saving can be directly effected through the suppression of visible smoke, it is nevertheless true that the process of smoke suppression may open channels through which important benefits may accrue. For example, the suppression of smoke implies the substitution of good for poor fire-room practice. If the fire-room is large, smoke abatement implies the use, the proper maintenance and the skillful manipulation of automatic firing devices. If the fire-room is small, it implies the exercise of superior skill and intelligence on the part of the fireman. In general, smoke suppression involves a reorganization of fire-room administration and methods, and a reorganization stimulated for the purpose of reducing smoke opens the way to other reforms, the total effect of which may constitute a material saving in the operation of the plant.

105.20 Visibility as a Standard of Measure: Attention has already been called (section 105.02) to the insufficiency of any standard of measure applied to smoke which is based upon visibility. There are other properties of smoke which, from the standpoint of atmospheric pollution, may be equally or more important. These are hereinafter treated in detail. The discussion thus far has concerned visibility alone.

SOLID CONSTITUENTS OF SMOKE

105.21 Origin of Solids in Smoke: The solid constituents of smoke have their origin in fuel and in materials which are burned, heated, reduced or refined by fire. Fires under boilers, including those of locomotives, consume more than three-quarters of all the solid fuel burned within the Area of Investigation (chapter 104), and the solids in smoke arising from such fires are entirely of fuel origin. In the case of metallurgical and other fires incident to certain industrial activities, the solid constituents of smoke may include, with those of fuel origin, solid particles from other sources, such as clay dust from brick and pottery kilns, clinker dust from cement plants and metallic dust from converters and other furnaces used for reducing or refining metals.

It is the Committee's purpose to present the results of an exhaustive investigation conducted to determine the physical and chemical characteristics of the solid constituents of smoke, the extent to which they pollute the atmosphere of Chicago and the degree to which the several services contribute to their production.

105.22 Solid Constituents of Steam Locomotive Smoke: Information concerning the solid constituents of locomotive smoke has been derived from two series of investigations in which the solid discharges from the smoke-stack were measured. These embraced:

1. Service tests conducted in connection with locomotives operating in yard and transfer services within the Area of Investigation.
2. Laboratory tests conducted in connection with a locomotive mounted upon a testing plant, and supplemented by tests on locomotives operating in through passenger, through freight and suburban passenger services in the Area of Investigation, to determine rates of combustion.

In both of these series of tests all or a known portion of the solid emissions from the smoke-stack were entrained and deposited in an arrester from which they could be collected for analysis. All of these tests, both in service and in the laboratory, were based upon elaborate and carefully considered plans, the purpose of which was to develop an accurate basis for a determination of the amount and character of the solid constituents of locomotive smoke. As a result of these tests, numerous samples of the solids contained in locomotive smoke were collected and weighed. The samples were then analyzed and classified as follows:

SOLID CONSTITUENTS OF SMOKE—PHYSICAL CLASSIFICATION OF ELEMENTS

Coarse cinders. Solid particles which remain upon a coarse sieve of 20 meshes to the inch (400 apertures per square inch).

Fine cinders. Solid particles which pass through the coarse sieve and remain upon a fine sieve of 200 meshes to the inch (40,000 apertures per square inch).

Fuel dust. Solid particles which pass through the fine sieve.

SOLID CONSTITUENTS OF SMOKE—CHEMICAL CLASSIFICATION OF ELEMENTS

Cinders and fuel dust. Tarry matter (hydrocarbons). Combustible matter (carbon). Mineral matter (ash, non-combustible). Sulphur.

105.23 Tests on Steam Locomotives in Yard and Transfer Services: In the development of these tests a mechanical trap or arrester was devised, the details of which were so arranged that the arrester could be attached to a locomotive stack in such position as to intercept and entrain a definite portion of the stream discharged. The construction of the arrester was such that the velocity of the intercepted portion of the discharge was gradually reduced and the solid materials were allowed to settle upon the bottom of the device from which they could be collected. The appearance of the device and its construction are shown by fig. 19.

The receiving orifice of the collecting tube of the arrester has the shape of a sector of a circle. When the arrester is attached to the stack of a locomotive under test, the receiving orifice of the collecting tube extends over the top of the stack in such manner that the point of the sector rests over the center of the stack. The ratio of the area of the orifice to the area of the stack determines the proportion of the total stream, emitted from the stack, which is received by the collector. In the device used in the tests under consideration, a portion constituting approximately 10 per cent of the total discharge is intercepted, the remaining 90 per cent passing undisturbed on its course into the atmosphere. The intercepted portion of the stream is projected into the orifice at high velocity and is conducted into the chamber of the arrester in such manner as to carry, by centrifugal action, the solid constituents to the outer portions of the interior space from which they settle to the bottom; the gases meanwhile, having their velocity reduced, find an exit through a screened aperture at the center and top of the chamber. The device makes ample provision for the retention in the bottom of the arrester of the materials entrained, from which point they may be removed from time

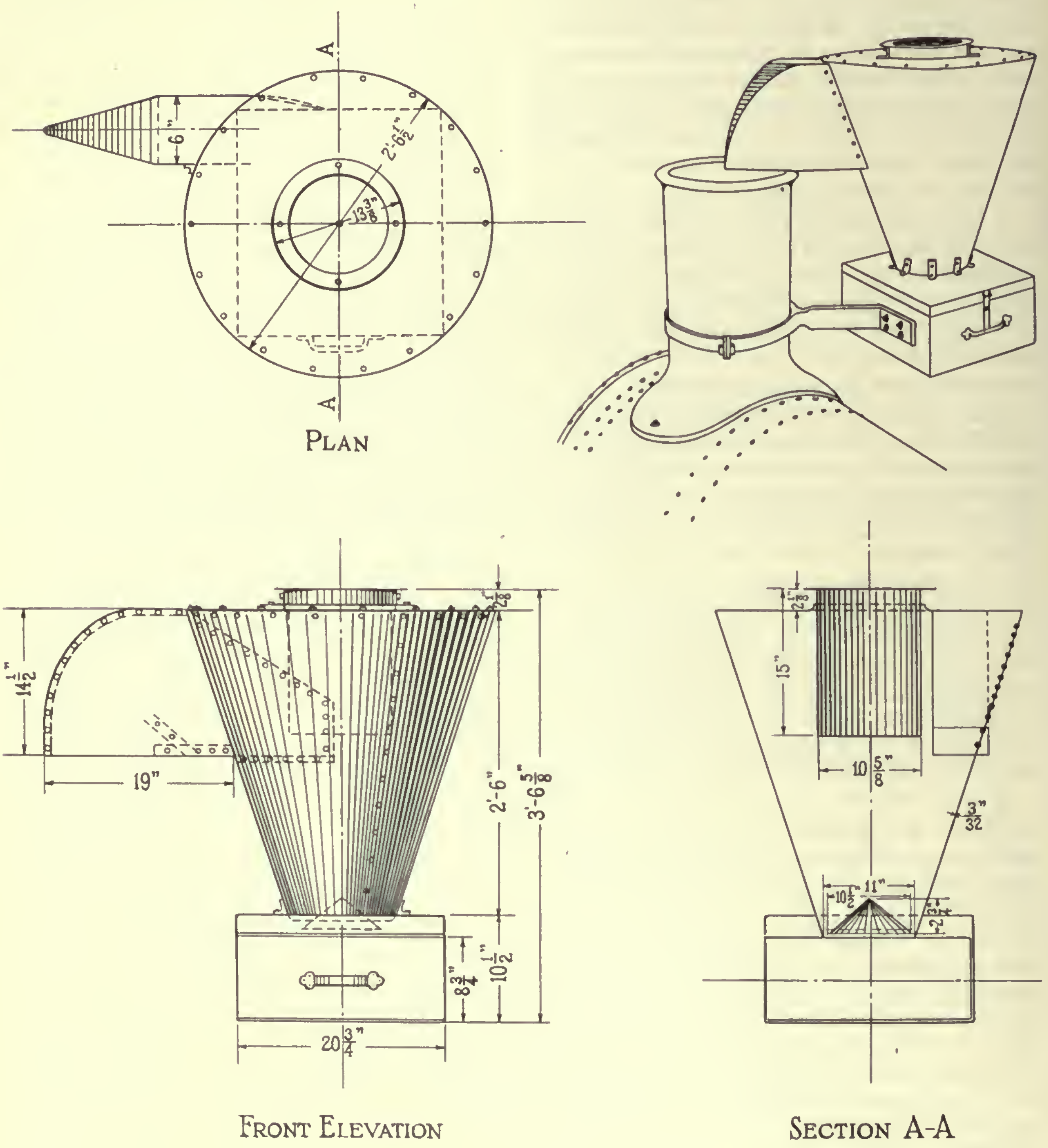

FIG. 19. MECHANICAL CINDER ARRESTER SHOWING POSITION WHEN ATTACHED TO LOCOMOTIVE SMOKE-STACK

to time. The samples of the solid constituents of smoke collected in this manner were weighed, classified and analyzed in the laboratory.

The tests were conducted by inspectors who recorded data relating to these determinations and other phases of the investigation. For the present purpose, it will be sufficient to state that the inspectors' records of the number of scoopsful of coal fired were used for determining the amount of coal consumed by the locomotive, both while running and while standing, during the periods of the tests. The average weight of a scoopful of coal was ascertained by experiment. From these data the relation between the solid constituents of locomotive smoke and the fuel consumed was established.

By the methods described, 41 tests were conducted on steam locomotives operating in the yard and transfer services of Chicago terminals. Bituminous coal was used for some of these tests and Pocahontas coal for others. The relation between the solids discharged through the stack and the fuel consumed, as determined by these tests, is set forth by table LXXXIII.*

TABLE LXXXIII. RELATION BETWEEN THE SOLID CONSTITUENTS OF STEAM LOCOMOTIVE SMOKE AND THE FUEL FIRED. TESTS ON LOCOMOTIVES IN YARD AND TRANSFER SERVICES IN THE AREA OF INVESTIGATION

Service	Test No.	Kind of Fuel	Amount of Solid Constituents in Smoke								Average Rate of Combustion lb. of Coal per Square Foot of Grate Surface per Hour		Per Cent of Total Time in Motion
			In Pounds per Ton of Fuel Fired				In Per Cent of Fuel Fired						
			Coarse Cinders	Fine Cinders	Fuel Dust	Total	Coarse Cinders	Fine Cinders	Fuel Dust	Total	Running	Standing	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Yard	359	Poc.	1.34	12.48	30.82	44.64	0.067	0.624	1.541	0.232	23.2	3.3	49.71
	360	"	1.04	13.40	36.60	51.04	0.052	0.670	1.830	2.552	37.1	7.7	62.78
	361	"	1.68	11.84	26.12	39.64	0.084	0.592	1.306	1.982	38.5	4.9	53.22
	362	"	1.56	8.92	22.92	33.40	0.078	0.446	1.146	1.670	38.4	4.3	50.10
	364	"	0.88	1.94	6.22	9.04	0.044	0 097	0.311	0.452	29.3	13.8	71.99
	Avg.	"	1.30	9.72	24.54	35.56	0.065	0.486	1.227	1.778			
	300	Bit.	0.88	1.06	0.84	2.78	0.044	0.053	0.042	0.139	28.9	22.0	87.64
	301	"	0.66	2.30	1.96	4.92	0.033	0.115	0.098	0.246	30.9	8.3	76.12
	302	"	0.78	1.46	0.84	3.08	0.039	0.073	0.042	0.154	31.3	11.6	68.68
	303	"	1.24	3.78	1.88	6.90	0.062	0.189	0.094	0.345	45.9	27.8	67.37
	304	"	1.02	4.20	2.06	7.28	0.051	0.210	0.103	0.364	47.6	24.8	66.06
	308	"	0.78	3.48	0.96	5.22	0.039	0.174	0.048	0.261	46.6	6.5	40.62
	309	"	0.72	4.20	1.52	6.44	0.036	0.210	0.076	0.322	53.5	6.4	36.98
	313	"	1.18	10.54	9.40	21.12	0.059	0.527	0.470	1.056	24.2	10.0	37.23
	314	"	2.54	10.76	8.98	22.28	0.127	0.538	0.449	1.114	23.0	4.4	41.65
	315	"	1.94	8.98	6.50	17.42	0.097	0.449	0.325	0.871	22.1	7.0	28.99
	316	"	1.66	7.48	6.60	15.74	0.083	0.374	0.330	0.787	33.4	8.8	38.51
	317	"	0.54	2.06	4.44	7.04	0.027	0.103	0.222	0.352	41.5	8.3	44.86
	318	"	0.28	3.00	6.98	10.26	0.014	0.150	0.349	0.513	34.2	6.0	38.14
	319	"	0.78	4.88	10.20	15.86	0.039	0.244	0.510	0.793	26.1	7.1	43.04
	320	"	0.22	1.94	3.72	5.88	0.011	0.097	0.186	0.294	57.0	11.5	47.72
	321	"	0.98	4.00	7.40	12.38	0.049	0.200	0.370	0.619	30.2	5.1	43.76
	350	"	0.40	1.46	1.40	3.26	0.020	0.073	0.070	0.163	55.1	7.8	65.60
	351	"	0.12	0.72	2.44	3.28	0.006	0.036	0.122	0.164	42.5	27.9	65.99
	352	"	0.30	2.18	7.50	9.98	0.015	0.109	0.375	0.499	43.3	9.7	76.03
	353	"	0.14	1.02	3.14	4.30	0.007	0.051	0.157	0.215	49.6	6.3	71.10
	354	"	0.30	1.44	7.72	9.46	0.015	0.072	0.386	0.473	56.6	5.2	71.12
	355	"	0.52	1.46	6.24	8.22	0.026	0.073	0.312	0.411	43.1	11.4	55.19
	356	"	0.46	1.20	5.34	7.00	0.023	0.060	0.267	0.350	48.4	15.7	63.56
	357	"	0.32	0.60	2.52	3.44	0.016	0.030	0.126	0.172	54.5	19.4	67.26
	358	"	0.52	2.34	12.80	15.66	0.026	0.117	0.640	0.783	37.2	3.3	51.95
	363	"	0.62	2.50	12.76	15.88	0.031	0.125	0.638	0.794	52.6	9.4	57.56
	Avg.	"	0.76	3.42	5.24	9.42	0.038	0.171	0.262	0.471			
Freight Transfer	365	Poc.	3.80	12.50	29.60	45.90	0.190	0.625	1.480	2.295	24.1	5.0	67.49
	366	"	0.76	1.92	4.00	6.68	0.038	0.096	0.200	0.334	44.5	10.6	55.68
	367	"	0.98	9.36	25.30	35.64	0.049	0.468	1.265	1.782	33.2	12.3	61.81
	Avg.	"	1.84	7.92	19.64	29.40	0.092	0.396	0.982	1.470			
	305	Bit.	0.24	1.52	1.94	3.70	0.012	0.076	0.097	0.185	51.0	9.1	41.04
	306	"	0.38	2.20	2.72	5.30	0.019	0.110	0.136	0.265	34.4	8.2	55.87
	307	"	0.34	2.62	3.48	6.44	0.017	0.131	0.174	0.322	30.9	9.2	58.22
	368	"	1.34	1.94	7.20	10.48	0.067	0.097	0.360	0.524	37.6	10.0	61.36
	369	"	0.54	2.08	4.06	6.68	0.027	0.104	0.203	0.334	27.3	7.2	65.57
	370	"	1.08	2.92	5.26	9.26	0.054	0.146	0.263	0.463	28.9	7.1	73.21
	371	"	0.42	1.90	6.58	8.90	0.021	0.095	0.329	0.445	28.6	9.2	72.44
	Avg.	"	0.62	2.16	4.46	7.24	0.031	0.108	0.223	0.362			

105.24 Laboratory Tests to Determine the Amount of Solids in Locomotive Smoke: Since any method which could be satisfactorily applied in service was found impracticable for determining the amount of solid matter contained in smoke arising from locomotives while operating at high speed, data relating to the amount of solids emitted in smoke at various rates of combustion were

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* A series of tests in which the density of smoke emissions from locomotives was observed and the composition of the smoke discharges was determined by analyses, was conducted by the Engineer of Tests of the Atchison, Topeka & Santa Fe Railway in the fall of 1911. A complete record of the tests and of the results is set forth in Bulletin VI, Vol. I, of the publications of the Committee, entitled "Reports of Tests made by the Atchison, Topeka & Santa Fe Railway Company in Smoke Abatement and in Analysis of Smoke Gases on Switch Engines—Chicago Yards." The processes employed were essentially the same as those used in the Committee's service tests and the results agree, on the whole, with those of the Committee's determinations. A copy of this publication is preserved in the Archives of the Committee, Vol. B 1.

secured by means of a series of tests conducted under the direction of the Chief Engineer of the Committee at the locomotive testing laboratory of the Pennsylvania Railroad at Altoona, Pa. This laboratory is equipped to receive a locomotive in such manner as to permit its operation to be observed and its performance to be studied while the engine is run under any desired conditions of speed, load or steam pressure. The plan of mounting involves a set of supporting wheels on which rest the drivers of the locomotive to be tested. The supporting wheels are mounted upon axles which revolve in fixed bearings and to which are attached hydraulic brakes for absorbing the power developed by the locomotive. The draw-bar of the locomotive couples to a dynamometer which measures and records the tractive force exerted by the locomotive. Ample accessory apparatus in the form of weighing and measuring devices of many sorts is provided. The fixed position of this equipment in the laboratory during the operation of the locomotive permits the performance of locomotives to be determined with a high degree of accuracy. The accessory equipment also includes a cinder arrester which serves to entrain the solid materials in the smoke emitted from the stack of the locomotive under test. The cinder arrester, unlike that employed in the tests on locomotives in yard and transfer services (section 105.23), is of large capacity and receives the entire stream discharged from the smoke-stack. It serves gradually to reduce the velocity of the stream, and thereby permits the solids to settle to the bottom of the arrester, where provision is made for their retention during an entire test.

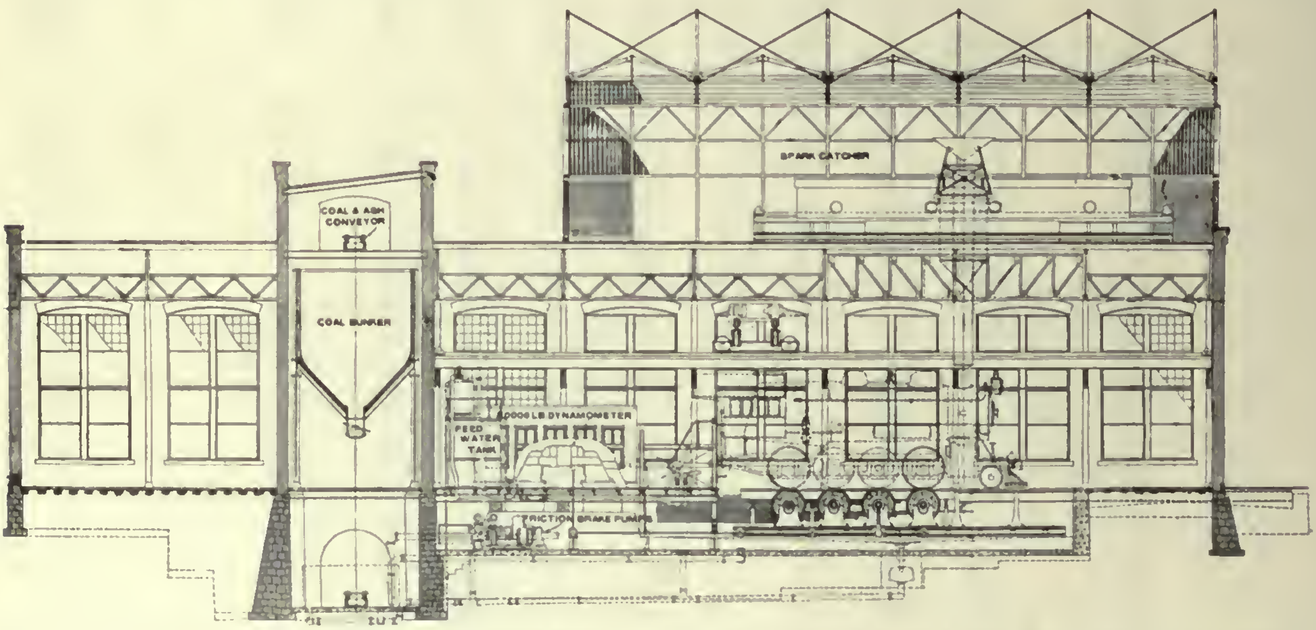

FIG. 20. LONGITUDINAL SECTION OF LOCOMOTIVE TESTING PLANT OF THE PENNSYLVANIA RAILROAD AT ALTOONA, PA.

Views of the locomotive testing plant at Altoona are presented as figs. 20 and 21.

The locomotive used in all laboratory tests made under the direction of the Committee was a consolidation freight locomotive of the Pennsylvania type H-8-B, weighing 238,300 pounds. A diagram giving its general dimensions is presented as fig. 22, and an illustration of the locomotive as it appeared when mounted on the testing laboratory is presented as fig. 23.

Coal for the tests was selected by the Committee's staff, in carload lots, from stocks in Chicago railroad yards and shipped from Chicago to Altoona. In the selection of fuel, it was the purpose to include coal which could be accepted as typical of the fuel used by the railroads entering Chicago. Six carloads of the coal came from six counties in Illinois which, in 1911, supplied a total of 57 per cent of all the fuel consumed by the railroads in the Chicago terminals, and four carloads came from four counties in Indiana which, in 1911, supplied a total of 31 per cent of such fuel.

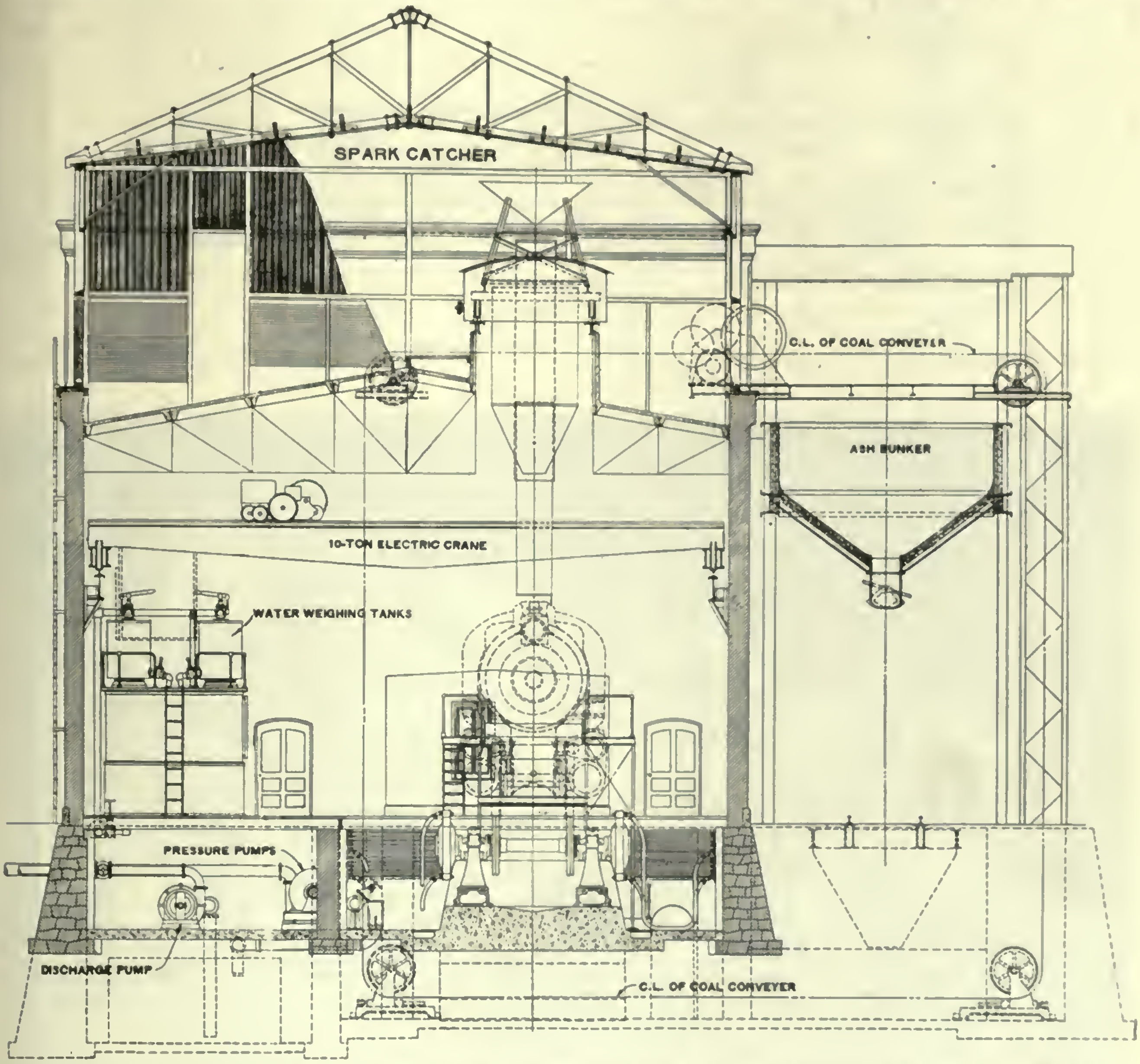

FIG. 21. CROSS-SECTION OF LOCOMOTIVE TESTING PLANT OF THE PENNSYLVANIA RAILROAD AT ALTOONA, PA.

A series of 4, 5 or 6 tests was conducted with each of the different coals selected, in preparation for which the locomotive fire-box was equipped with a brick arch. An additional series of tests involving the use of four samples of coal was conducted without the brick arch in the fire-box. Individual tests generally covered a period of two hours, during which no change was made in the conditions under which the locomotive was operated or in the rate of firing. In the progress of a few tests the coal used, when burned at the predetermined maximum rate of combustion, would not maintain the required steam pressure for a period of two hours, and for these tests the results of a shorter period were accepted. All tests were conducted with throttle fully open, the speed being controlled by the load. The facts recorded for each test included the amount of fuel consumed, the cinders and fuel dust emitted, the ash and clinker discharged, the water evaporated, the tractive effort exerted, the power

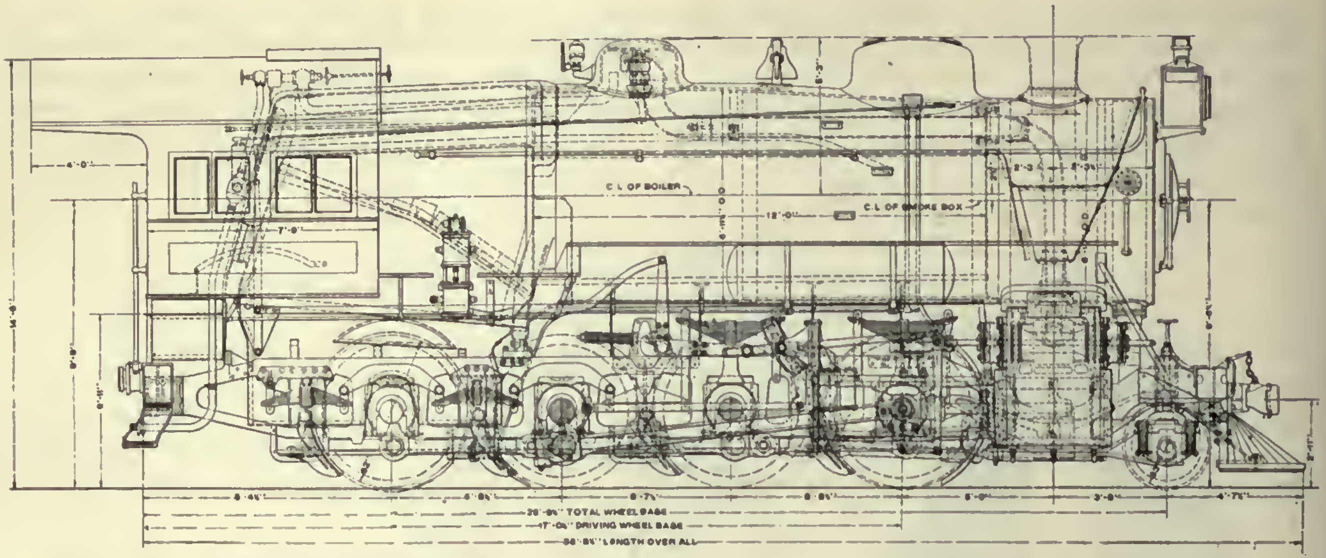

FIG. 22. GENERAL DIMENSIONS OF LOCOMOTIVE USED IN LABORATORY TESTS AT ALTOONA, PA.

FIG. 23. VIEW OF LOCOMOTIVE MOUNTED ON THE TESTING PLANT AT ALTOONA, PA.

developed, the draft at different rates of combustion, and such other facts as were needed to define completely the performance of the locomotive.* The materials collected in the arrester were weighed and analyzed to disclose both their physical and chemical properties. Samples of the gases emitted from the smoke-stack were also procured and analyzed in a manner which will be hereinafter set forth.

A total of 76 tests was made. They occupied the time of an expert staff of engineers and laboratory assistants, consisting of 30 men, for a period of approximately two months.

The facts set forth by the Altoona tests, with reference to the quantity and the physical characteristics of the solids contained in the smoke emissions in their relation to the fuel fired, are presented as table LXXXIV.

From the values set forth in table LXXXIV, a curve was plotted for each sample of coal, to indicate the relation between the quantity of solids emitted from the locomotive stack and the quantity of fuel consumed at the several rates of combustion employed with the fuel in question. The maximum rate of combustion for each sample of fuel tested was more than 80 pounds per square foot of grate surface per hour, and, in all except two cases, was more than 100 pounds per square foot of grate surface per hour. The minimum rate of combustion for the several coals varied from 23 to 27 pounds per square foot of grate surface per hour. It was assumed in plotting the curves that the solids emitted diminished uniformly below these minimum rates of combustion employed in the tests, so that when the rate of combustion reached zero there would be no discharge of solids from the stack. From the series of curves thus plotted, presenting the emission rates of solids for the several samples of fuel, values were taken for rates of combustion ranging from 10 to 100 pounds of coal per square foot of grate surface per hour, the increase proceeding by increments of 10. The emission rates thus obtained for all fuels tested were averaged for each rate of combustion, and the average values were used in plotting a working diagram showing the percentage of the fuel burned which appears as solids in the smoke, as averaged from all tests made. This diagram is presented as fig. 24.

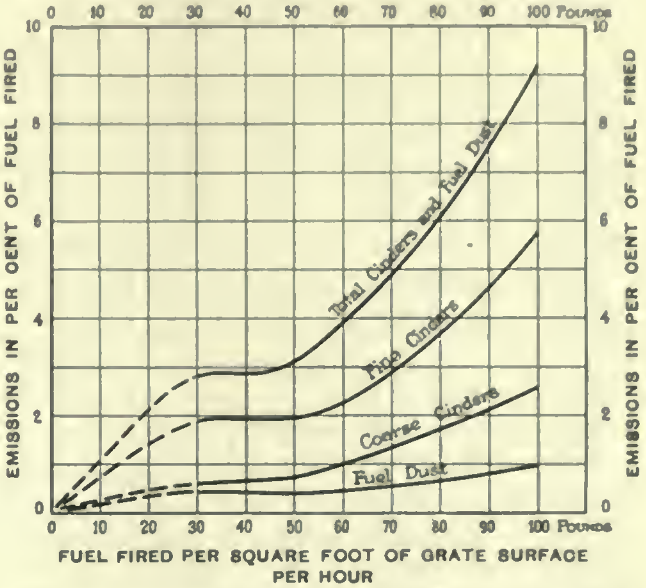

FIG. 24. DIAGRAM OF CINDERS AND DUST. Amount of Solid Constituents of Smoke Emitted by a Locomotive on a Testing Plant when Burning Illinois and Indiana Coals at Various Rates of Combustion.

105.25 Methods of Applying the Results of Service and Laboratory Tests to the Determination of the Amount of Solids Emitted in Smoke from Steam Locomotives Operating in Road Service within the Area of Investigation: A basis for determining the quantity of solids emitted in the smoke arising from locomotives in yard service, in freight transfer service and in passenger transfer service within the Area of Investigation, is supplied by tests made upon locomotives operating in these services, a description of which has already been presented (section 105.23). The average emission factors thus obtained, setting forth the relation between the solids emitted in smoke and the fuel consumed (table LXXXIV), when applied to the known quantity of fuel consumed in the service in question, give the total quantity of solids contained in the smoke arising from such service.

A basis for the determination of the quantity of solids emitted in the smoke arising from locomotives operating in through passenger service, in suburban passenger service and in through freight service, is supplied by the results of the locomotive laboratory tests already described (section 105.24), and summarized by the diagram,

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*Other facts derived from these tests have been made the basis of other studies by the Committee, the results of which are presented in the Appendix, sections 701.44 to 701.58. A complete record of the methods employed and the results obtained from the Altoona tests is preserved in the Archives of the Committee, Vol. G 34, being a series of test reports submitted under the authority of C. D. Young, Engineer of Tests, Pennsylvania Railroad.

TABLE LXXXIV. RELATION BETWEEN THE SOLID CONSTITUENTS OF STEAM LOCOMOTIVE SMOKE AND AMOUNT OF FUEL FIRED. LOCOMOTIVE LABORATORY TESTS MADE AT ALTOONA, PA.

Test Number	Rev. per Min.	Miles per Hour	Smoke Density Per Cent	Fuel Fired Lb. per Sq. Ft. Grate per Hr.	Amount of Solid Constituents in Smoke							
					In Pounds per Ton of Fuel Fired				In Per Cent of Fuel Fired			
					Coarse Cinders	Fine Cinders	Fuel Dust	Total	Coarse Cinders	Fine Cinders	Fuel Dust	Total
Coal from Macoupin County, Illinois												
2715	40	7.33	24	23.7	5.78	33.92	6.40	46.10	0.289	1.696	0.320	2.305
2716	80	14.66	30	53.7	14.96	30.72	5.52	51.20	0.748	1.536	0.276	2.560
2717	80	14.66	38	80.1	36.40	59.68	7.08	103 16	1.820	2.984	0.354	5.158
2718	100	18.33	42	91.6	52.30	75.40	6.52	134.22	2.615	3.770	0.326	6.711
* 2719	80	14.66	42	63.6	13.30	34.94	3.18	51.42	0.665	1.747	0.159	2.571
2720 †	40	7.33	18	25.0	9.52	37.56	3.24	50.32	0.476	1.878	0.162	2.516
2721 †	80	14.66	20	49.3	9.04	28.94	5.32	43.30	0.452	1.447	0.266	2.165
2722 †	80	14.66	24	74.0	33.92	43.92	5.72	83.56	1.696	2.196	0.286	4.178
2723 †	100	18.33	42	110.2	55.56	81.14	16.06	152.76	2.778	4.057	0.803	7.638
2724 †	120	22.00	40	107.1								
Coal from Marion County, Illinois												
2796 †	40	7.33	24	31.6	11.14	37.22	11.14	59.50	0.557	1.861	0.557	2.975
2797 †	80	14.66	14	47.6	26.00	43.18	7.26	76.44	1.300	2.159	0.363	3.822
2798 †	80	14.66	26	83.0	52.12	52.40	20.26	124.78	2.606	2.620	1.013	6.239
2799 †	80	14.66	14	51.0	10.68	36.92	3.70	51.30	0.534	1.846	0.185	2.565
* 2700 †	80	14.66	30	63.3	20.24	21.64	11.70	53.58	1.012	1.082	0.585	2.679
Coal from Saline County, Illinois												
2790 †	40	7.33	28	27.1	6.88	29.08	6.04	42.00	0.344	1.454	0.302	2.100
2791 †	80	14.66	24	43.4	7.02	24.54	5.24	36.80	0.351	1.227	0.262	1.840
2792 †	80	14.66	30	64.1	19.82	61.44	9.90	91.16	0.991	3.072	0.495	4.558
2793 †	100	18.33	64	116.1	40.48	80.94	14.80	136.22	2.024	4.047	0.740	6.811
2794 †	120	22.00	78	111.7								
* 2795 †	80	14.66	64	64.3	25.72	46.88	9.48	82.08	1.286	2.344	0.474	4.104
Coal from Sangamon County, Illinois												
2732 †	40	7.33	20	26.3	8.92	40.58	12.36	61.86	0.446	2.029	0.618	3.093
2733 †	80	14.66	18	47.7	8.92	24.22	5.28	38.42	0.446	1.211	0.264	1.921
2734 †	80	14.66	22	69.1	8.96	44.70	8.96	62.62	0.448	2.235	0.448	3.131
2735 †	100	18.33	30	105.6	60.56	58.98	8.28	127.82	3.028	2.949	0.414	6.391
2736 †	120	22.00	42	109.6								
* 2737 †	80	14.66	52	46.7	10.28	56.76	8.12	75.16	0.514	2.838	0.406	3.758
Coal from Vermillion County, Illinois												
2748 †	40	7.33	22	24.4	7.24	31.28	10.30	48.82	0.362	1.564	0.515	2.441
2749 †	80	14.66	22	47.0	12.32	37.78	7.56	57.66	0.616	1.889	0.378	2.883
2750 †	80	14.66	22	63.7	37.18	35.14	5.76	78.08	1.859	1.757	0.288	3.904
2751 †	100	18.33	26	105.0	56.04	107.52	15.32	178.88	2.802	5.376	0.766	8.944
2752 †	120	22.00	50	122.7								
* 2753 †	80	14.66	36	60.7	11.06	29.44	4.74	45.24	0.553	1.472	0.237	2.262
Coal from Williamson County, Illinois												
2725	40	7.33	18	25.6	10.76	41.52	10.00	62.28	0.538	2.076	0.500	3.114
2726	80	14.66	24	49.2	12.30	16.66	14.66	43.62	0.615	0.833	0.733	2.181
2727	80	14.66	24	76.9	39.90	78.44	20.54	138.88	1.995	3.922	1.027	6.944
2728	100	18.33	32	105.2	98.92	90.60	24.12	213.64	4.946	4.530	1.206	10.682
2729	120	22.00	70	136.6								
* 2730	80	14.66	20	47.6	5.88	46.24	15.60	67.72	0.294	2.312	0.780	3.386
2731	40	7.33	..	.....	13.12	14.66	4.56	32.34	0.656	0.733	0.228	1.617
2738 †	40	7.33	12	25.6	27.88	24.26	3.98	56.12	1.394	1.213	0.199	2.806
2739 †	80	14.66	14	47.3	16.24	35.94	2.56	54.74	0.812	1.797	0.128	2.737
2740 †	80	14.66	18	68.3	12.08	22.38	3.82	38.28	0.604	1.119	0.191	1.914
2741 †	100	18.33	32	102.5	14.44	28.64	4.12	47.20	0.722	1.432	0.206	2.360
* 2742 †	80	14.66	16	53.7	19.42	53.06	9.98	82.46	0.971	2.653	0.499	4.123
Coal from Greene County, Indiana												
2743 †	40	7.33	22	24.7	3.86	30.58	10.08	44.52	0.193	1.529	0.504	2.226
2744 †	80	14.66	8	43.3	40.12	105.58	12.08	157.78	2.006	5.279	0.604	7.889
2745 †	80	14.66	16	59.2	42.32	76.34	10.20	128.86	2.116	3.817	0.510	6.443
2746 †	100	18.33	26	92.2	53.72	121.80	27.46	202.98	2.686	6.090	1.373	10.149
* 2747 †	80	14.66	26	53.0	26.72	66.86	14.04	107.62	1.336	3.343	0.702	5.381
Coal from Sullivan County, Indiana												
2780 †	40	7.33	28	27.1	16.06	37.36	8.94	62.36	0.803	1.868	0.447	3.118
2781 †	80	14.66	20	46.0	9.22	37.10	5.92	52.24	0.461	1.855	0.296	2.612
2782 †	80	14.66	24	66.2	18.54	51.42	14.32	84.28	0.927	2.571	0.716	4.214
2783 †	100	18.33	38	99.3	52.10	82.10	13.80	148.00	2.605	4.105	0.690	7.400
2784 †	120	22.00	70	*32.3								
* 2785 †	80	14.66	52	67.8	11.98	36.92	5.22	54.12	0.599	1.846	0.261	2.706
2786	40	7.33	44	29.9	13.30	47.78	6.38	67.46	0.665	2.389	0.319	3.373
2787	80	14.66	46	46.8	8.80	36.90	4.92	50.62	0.440	1.845	0.246	2.531
2788	80	14.66	52	77.2	24.56	65.62	7.92	98.10	1.228	3.281	0.396	4.905
2789	100	18.33	62	93.1	51.94	189.80	16.92	258.66	2.597	9.490	0.846	12.933
Coal from Vermillion County, Indiana												
2760 †	40	7.33	28	27.1	25.22	84.34	29.20	138.76	1.261	4.217	1.460	6.938
2761 †	80	14.66	16	45.8	10.70	46.06	4.40	61.16	0.535	2.303	0.220	3.058
2762 †	80	14.66	20	68.9	22.66	60.82	11.50	94.98	1.133	3.041	0.575	4.749
2763 †	100	18.33	34	104.4	56.64	129.70	13.82	200.16	2.832	6.485	0.691	10.008
2764 †	120	22.00	48	115.3								
* 2765 †	80	14.66	28	56.2	27.58	69.96	9.82	107.36	1.379	3.498	0.491	5.368
2766	40	7.33	40	27.2	5.74	25.60	3.28	34.62	0.287	1.280	0.164	1.731
2767	80	14.66	26	50.5	17.24	47.16	6.34	70.74	0.862	2.358	0.317	3.537
2768	80	14.66	42	75.7	40.00	92.02	9.86	141.88	2.000	4.601	0.493	7.094
2769	100	18.33	48	101.0	48.02	190.32	18.58	256.92	2.401	9.516	0.929	12.846
Coal from Vigo County, Indiana												
2754 †	40	7.33	24	26.6	7.22	27.70	6.06	40.98	0.361	1.385	0.303	2.049
2755 †	80	14.66	20	46.8	19.02	57.64	7.44	84.10	0.951	2.882	0.372	4.205
2756 †	80	14.66	22	70.7	15.98	61.88	12.10	89.96	0.799	3.094	0.605	4.498
2757 †	100	18.33	34	115.6	23.32	81.70	16.46	121.48	1.166	4.085	0.823	6.072
2758 †	120	22.00	58	136.6								
* 2759 †	80	14.66	22	51.7	27.16	66.74	19.32	113.18	1.356	3.337	0.966	5.659

* Fired by an inexperienced fireman. † With brick arch in fire-box.

fig. 24. It is shown by this diagram that the amount of solids emitted in smoke is a function of the rate of combustion. If the average rate of combustion incident to the operation of a locomotive in any particular service is known, the amount of solids emitted by locomotives operating in that service can be taken from the diagram.

To establish the rates of combustion attending the normal operation of locomotives in through and suburban services in Chicago. a series of 298 tests was made on locomotives operating within the Arca of Investigation. Two men were employed in each test. The observers recorded many facts incident to the operation of each locomotive inspected, the more important of which were the work performed and the rate at which fuel was consumed. The rate of fuel consumption was found by counting the scoopfuls of coal fired, the value of the average scoopful having been carefully determined. Records of the coal fired while running and while standing were kept separately. It was assumed that solids were emitted only while locomotives were in motion, the exhaust steam being regarded as supplying the force which lifts the solid particles from the fire-box. The grate area of each locomotive was obtained from the railroads. From facts thus established the hourly rate of combustion per square foot of grate surface and the per cent of fuel burned while running, for each of the several services involved, were determined to be as follows:

SERVICE	LB. PER SQ. FT. GRATE SURFACE PER HOUR	PER CENT OF FUEL FIRED WHILE RUNNING
Road freight	40.6	92.7
Through passenger	52.2	98.0
Suburban passenger	62.7	96.4

By combining these rates of combustion with values for the emission of solids as set forth by the diagram, fig. 24, and by multiplying the values thus obtained by the per cent of fuel fired while running, the emission factors for solids emitted by locomotives operating within the Area of Investigation were established. The emission factors for solid constituents of locomotive smoke thus determined, and also those for yard and transfer services as determined by the use of the cinder arrester in service tests (section 105.23), are presented as table LXXXV.

TABLE LXXXV. EMISSION FACTORS FOR SOLID CONSTITUENTS OF STEAM LOCOMOTIVE SMOKE

Service	Kind of Fuel	Solid Constituents of Smoke							
		In Pounds per Ton of Fuel Burned				In Per Cent of Fuel Burned			
		Coarse Cinders	Fine Cinders	Fuel Dust	Total	Coarse Cinders	Fine Cinders	Fuel Dust	Total
1	2	3	4	5	6	7	8	9	10
Yard......	Poc.	1.30	9.72	24.54	35.56	0.065	0.486	1.227	1.778
	Bit.	0.76	3.42	5.24	9.42	0.038	0.171	0.262	0.471
Road freight	Bit.	11.30	34.68	6.86	52.84	0.565	1.734	0.343	2.642
Freight transfer...	Poc.	1.84	7.92	19.64	29.40	0.092	0.396	0.982	1.470
	Bit.	0.62	2.16	4.46	7.24	0.031	0.108	0.223	0.362
*Passenger transfer...	Poc.	1.30	9.72	24.54	35.56	0.065	0.486	1.227	1.778
	Bit.	0.76	3.42	5.24	9.42	0.038	0.171	0.262	0.471
Through passenger .	Poc. Bit.	15.08	39.40	7.84	62.32	0.754	1.970	0.392	3.116
Suburban passenger .	Bit.	20.54	47.42	9.26	77.32	1.032	2.371	0.463	3.866

* The emission factors determined for locomotives in yard service were considered applicable to locomotives operating in passenger transfer service.

In the case of locomotives at locomotive terminals, it was not practicable to conduct an exhaustive series of tests with the cinder arrester which was used in connection with the service tests of locomotives in the yard and transfer services. Neither could the results of the Altoona tests be applied directly to a determination of the amount of solids emitted by locomotives at locomotive terminals, because no accurate determination could be made of the rates of combustion. The difficulties arose from the fact that the quantity of coal fired in preparing a locomotive for service at the round house is in excess of that actually consumed while at the terminal. An examination of the matter indicated that, for the purpose in question, yard service might be regarded as fairly representative of conditions prevailing in locomotive terminals, and the results obtained from actual tests in yard service were therefore applied in determining the amount of solids emitted by locomotives at locomotive terminals.

A discussion of the chemical properties of the solid constituents of locomotive smoke is reserved for section 105.30.

Closely related to the subject of solids in locomotive smoke, as already presented, is that which concerns the flight or spread of such solids after they leave the locomotive stack. It is evident that the effect of such solids in polluting the atmosphere will depend to some extent upon what becomes of them. For the purpose of establishing certain facts relating to the flight, quantity and character of those solids which normally settle to the ground on or near a railroad track, a series of field and laboratory experiments has been made, the results of which will

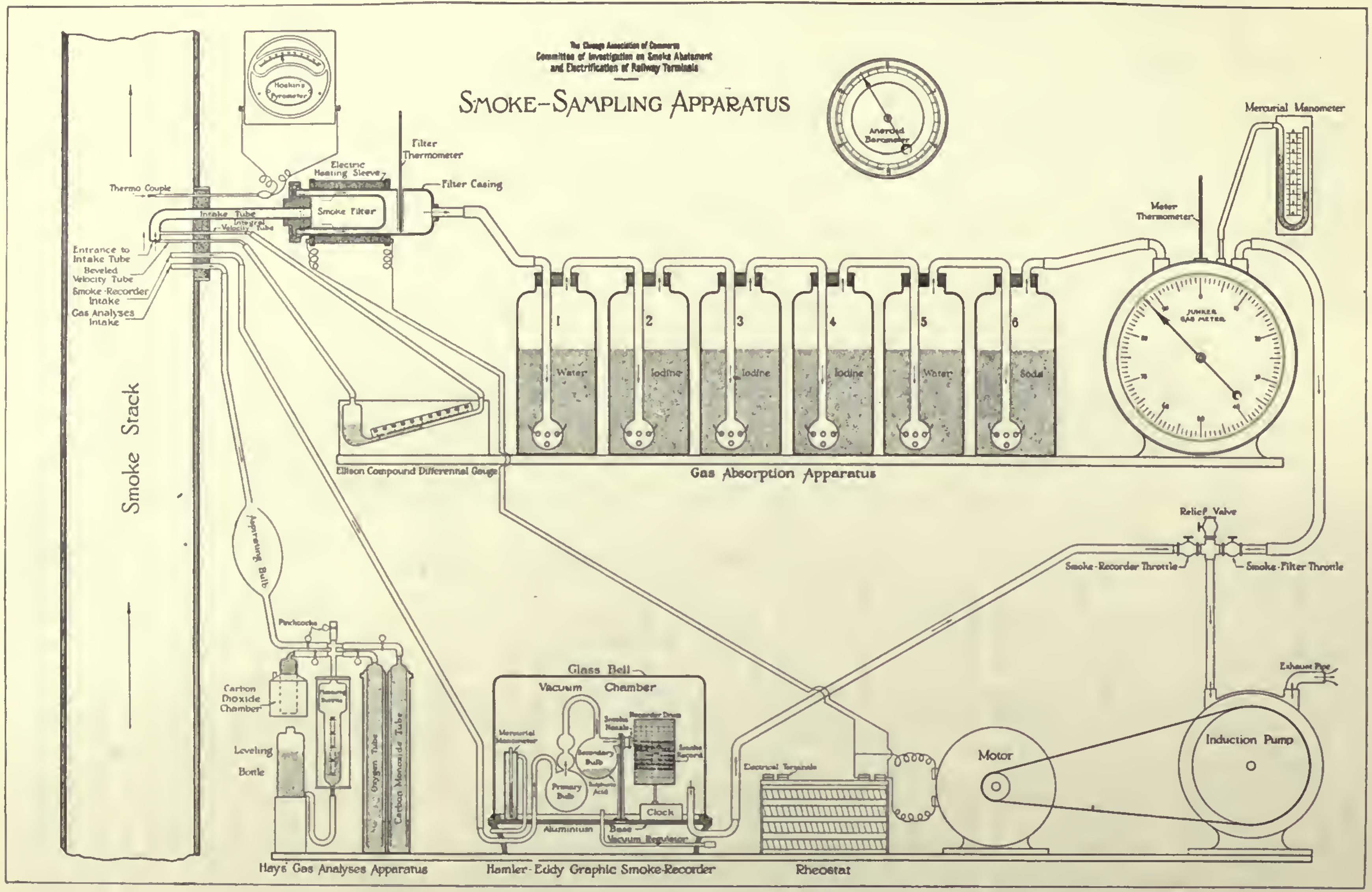

FIG. 25. SAMPLING APPARATUS AS CONNECTED TO A STATIONARY STACK UNDER TEST

be found set forth in the Appendix to this report, sections 701.37 to 701.43, inclusive.

105.26 The Solid Constituents of Smoke from Steam Vessels and Stationary Plants: The problem of determining the amount and character of the solid constituents of smoke from the stacks of steam vessels and of stationary plants has proved a difficult one. Such stacks usually operate under natural draft, and the velocity of flow through them as compared with that through the stack of a locomotive is comparatively low. The study of solids contained in smoke delivered from such stacks is a matter which has heretofore received but little attention and no fixed method of procedure is recognized. Methods of sampling which were found satisfactory in their application to locomotives, cannot be employed because the energy of the issuing stream is not sufficient to project the intercepted sample through the collecting apparatus. In place of the simple mechanical arrester which served for locomotives, there is required, for use in tests of stacks operating under natural draft, a considerable amount of delicate and complicated apparatus with the attention of skilled operators. Moreover, results which might readily be obtained from a locomotive test in an hour or two require, in tests of stacks under natural draft, a longer period of observation. To other requirements, therefore, there must be added that of a liberal allowance of time. The investigation of which a record is herein set forth, involving a determination of the amount and character of the solid constituents of smoke from steam vessels and stationary plants, constitutes a pioneer work. The methods employed have, to a considerable extent, been original, and the array of facts bearing on the subject which have been derived from the experiments is far more extensive than any which has hitherto been available.

All determinations are based upon the results of a process of sampling. Samples collected from representative stacks of each of the different classes of service were analyzed, and all results for each class of service were summarized to give a factor which could be applied to the known amount of coal consumed. An analysis of the samples was also made to determine the amount and character of the gaseous constituents of smoke, the results of which are elsewhere presented (section 105.38).

The apparatus employed in collecting and analyzing the samples of smoke emissions from steam vessels and stationary plants included a smoke filtering device, a suitable gas analysis apparatus, a mechanical smoke recorder, accessory equipment for recording temperatures and pressures, a pump to induce the flow of the gases through the apparatus, and equipment incident to its operation. An illustration of the apparatus, showing the manner in which it is connected to a stack under test, is presented as fig. 25.

The sampling of the smoke by means of the apparatus shown was accomplished by cutting a small opening through the wall of the stack through which to insert the intake tubes of the apparatus. This opening was always located as near the top of the stack as possible, and in no case at a distance of less than 2½ times the diameter of the stack above the breeching or above any bend or local enlargement in the stack. At such location the velocity of the flow of smoke through the entire cross-section of the stack was assumed to be sufficiently uniform to justify the assumption that a sample taken through a tube of small cross-section would be representative.

In considering the methods employed in determining the solid constituents of smoke, attention need be given only to the filtering device (fig. 25) by means of which the solid particles were entrained. The filter employed was made of the regular extraction shell used in the Brady filter, which, if kept dry, will withstand a pressure of about two pounds per square inch. In form the filter was cylindrical, having one end closed. It was held in proper position to receive the flow of the gas by means of a brass casing surrounded by an electric resistance coil which was employed to keep the filter at a temperature sufficiently high to free its contents of moisture. The filter was renewed as often as necessary during each test, and at the conclusion of the test the contents of all filters used were analyzed to determine the amount and character of the solids entrained.

The volume of the intercepted stream of gases which was drawn through the filter was measured by meter and, with the knowledge of the relation between the area of the aperture in the intake pipe of the apparatus and the area of the entire stack, the volume of the entire flow through the stack could be calculated, the velocity of flow

TABLE LXXXVI. AMOUNT OF SOLID CONSTITUENTS OF SMOKE FROM STEAM VESSELS, IN TERMS OF FUEL CONSUMED

Test No.	Fuel Consumed in Pounds per Hour		Observed Smoke Density Per Cent Ringelmann Method	Solid Constituents of Smoke							
				In Pounds per Ton of Fuel Consumed				In Per Cent of Fuel Consumed			
	Total	Per Sq. Ft. of Grate Surface		Coarse Cinders	Fine Cinders	Fuel Dust	Total	Coarse Cinders	Fine Cinders	Fuel Dust	Total
1	2	3	4	5	6	7	8	9	10	11	12
					Bituminous Coal						
55	1,440	17.14	1.90	1.70	12.14	10.60	24.44	0.085	0.607	0.530	1.222
Average				1.70	12.14	10.60	24.44	0.085	0.607	0.530	1.222
					Pocahontas Coal						
52	664	16.35	0	0	9.32	18.86	28.18	0	0.466	0.943	1.409
53	950	26.35	1.0	0	7.16	16.98	24.14	0	0.358	0.849	1.207
Average				0	8.02	17.78	25.80	0	0.401	0.889	1.290

TABLE LXXXVII. AMOUNT OF SOLID CONSTITUENTS OF SMOKE FROM HIGH PRESSURE STEAM STATIONARY POWER AND HEATING PLANTS, IN TERMS OF FUEL CONSUMED

Test No.	Fuel Consumed in Pounds per Hour		Observed Smoke Density Per Cent Ringelmann Method	Solid Constituents of Smoke							
				In Pounds per Ton of Fuel Consumed				In Per Cent of Fuel Consumed			
	Total	Per Sq. Ft. of Grate Surface		Coarse Cinders	Fine Cinders	Fuel Dust	Total	Coarse Cinders	Fine Cinders	Fuel Dust	Total
1	2	3	4	5	6	7	8	9	10	11	12
					Bituminous Coal						
13	1,200	21.40	0.49	0.20	1.40	11.40	13 00	0.010	0.070	0.570	0.650
14	800	22.20	3.76	0.40	6.20	16.20	22.80	0.020	0.310	0.810	1.140
79	1,415	20.20	0.05	0	11.16	17.78	28 94	0	0.558	0.889	1.447
29	4,225	23.50	14.50	0.22	6.06	10.16	16.44	0.011	0.303	0.508	0.822
30	4,995	14.60	15.80	0	0.22	12.70	12.92	0	0.011	0.635	0.646
20	2,500	35.70	0.96	0	1.12	3.80	4.92	0	0.056	0.190	0.246
21	3,415	31.60	0.45	0	0.48	3.06	3.54	0	0.024	0.153	0.177
22	1,335	26.60	0.71	0	3.00	15.20	18.20	0	0.150	0.760	0.910
23	330	9.20	10.78	0	0.82	12.20	13.02	0	0.041	0.610	0.651
24	335	5.60	8.05	0	1.08	11 20	12.28	0	0.054	0.560	0.614
56	5,000	19.20	0	0	2.94	7.30	10.24	0	0.147	0.365	0.512
57	5,000	19.20	0	0	1.74	4.22	5.96	0	0.087	0.211	0 298
80	4,500	25.00	0	0.98	59.88	20.58	81.44	0.049	2.994	1.029	4.072
81	4,500	25.00	0	0.26	19.26	16.74	36.26	0.013	0.963	0.837	1.813
82	1,330	13.30	1.45	0	40.18	19.46	59.64	0	2.009	0.973	2.982
83	4,000	11.75	2.20	0	4.70	9.12	13.82	0	0.235	0.456	0.691
84	2,765	21.40	0	0	0	4.06	4.06	0	0	0.203	0.203
85	3,980	29.14	0	0	3.08	6.44	9.52	0	0.154	0.322	0.476
90	3,665	32.73	3.09	0	11.76	26.20	37.96	0	0.588	1.310	1.898
91	5,000	16.67	2.02	0	3.06	12.98	16.04	0	0.153	0.649	0.802
92	4,000	13.33	3.46	0	2.78	11.20	13.98	0	0.139	0.560	0.699
93	2,900	26.85	0.21	0	3.86	7.56	11.42	0	0.193	0.378	0.571
94	2,428	25.31	0.95	0	8.80	12.94	21.74	0	0.440	0.647	1.087
95	2,608	31.06	1.35	0	2.02	5.52	7.54	0	0.101	0.276	0.377
96	1,715	14.30	2.31	0	7.30	26.70	34.00	0	0.365	1.335	1.700
1	952	26.50	13.85	0.60	6.40	22.80	29.80	0.030	0.320	1.140	1.490
2	1,445	14.70	0 66	0	4.40	6.20	10.60	0	0.220	0.310	0.530
3	4,000	32.70	21.97	0	5.80	10.80	16.60	0	0.290	0.540	0.830
4	3,945	38.10	0.89	0	4.80	12.00	16.80	0	0.240	0.600	0.840
5	1,872	19.70	9.62	0	0.60	2.40	3.00	0	0.030	0.120	0.150
6	2,080	18.90	6.88	0	0.60	3.40	4.00	0	0.030	0.170	0.200
7	2,300	17.20	12.00	0.40	7.60	13.40	21.40	0.020	0.380	0.670	1.070
8	2,300	21.30	6.26	0.20	13.20	35.80	49.20	0.010	0.660	1.790	2.460
9	3,200	39.50	3.15	0.08	2.80	6.00	8.88	0.004	0.140	0.300	0.444
10	5,245	39.50	20.00	0.20	6.40	15.60	22.20	0.010	0.320	0.780	1.110
12	2,000	41.70	3.68	0.04	1.80	5.40	7.24	0.002	0.090	0.270	0.362
15	12,000	41.70	0.58	0	2.00	6.00	8.00	0	0.100	0.300	0.400
17	28,000	32.80	20.00	0	2.12	15.06	15.06	0	0.160	0.647	0.753
18	23,450	32.60	0.94	0	1.64	5.62	7.26	0	0.082	0.281	0.363
33	470	23.50	6.77	0.32	0.86	14.98	16.16	0.016	0.043	0.749	0.808
65	1,670	13.95	29.50	0	6.84	20.74	27.58	0	0.342	1.037	1.379
66	1,675	13.95	28.31	0	2.74	25.06	27.80	0	0.137	1.253	1.390
86	1,065	16.68	0.67	0	0.98	4.96	5.94	0	0.049	0.248	0.297
87	1,290	20.18	0.30	0	2.30	8.03	10.36	0	0.115	0.403	0.518
88	2,000	17.86	1.38	0	1.66	11.14	12.80	0	0.083	0.557	0.640
89	2,000	17 86	4.29	0	1.74	9.62	11.36	0	0.087	0.481	0.568
Average				0.06	5.32	10.84	16.22	0.003	0.266	0.542	0.811
					Pocahontas Coal						
115	329	11.73	0.76	0	3.22	8.52	11.74	0	0.161	0.426	0.587
116	315	11.23	1 75	0	2.18	12.12	14.30	0	0.109	0.606	0.715
Average				0	2.26	10.72	12.98	0	0.113	0.536	0.649

through the apparatus being regulated by a differential gage to correspond to that through the stack.

In the case of tests made with the smoke sampling apparatus on steam vessels, it was necessary, because of the rolling motion of the vessel, to use two compound differential gages in maintaining the velocity of flow through the apparatus to correspond to that of the stream of gases through the stack.

Record was kept of the amount of fuel burned during each test. It was possible, therefore, to determine, from the results of the process described, the value for the solid constituents of smoke in terms of fuel consumed.

A total of 118 field tests was conducted with the smoke sampling apparatus. The results of seven of these tests, which related to oil burning furnaces, refuse destructors and Bessemer converters, were not used in determining the solid constituents of smoke from coal fires. The number of tests conducted on steam vessels, and in each of the several services involving stationary steam plants, excluding those the results of which were not used, is given in the following tabulation:

STEAM VESSELS	
Tugs and lighters	1
River barges, dredges, etc.	2
Lake steamers and barges	1
HIGH PRESSURE STEAM STATIONARY POWER AND HEATING PLANTS	
Public service corporation plants	5
Municipal plants	2
Steam railroad plants	5
Office buildings, hotels, etc.	17
Manufacturing plants	21
LOW PRESSURE STEAM AND OTHER STATIONARY HEATING PLANTS	
Buildings and apartments of more than three flats (subject to city inspection)	8
Buildings and apartments of three flats or less (not subject to city inspection)	20
FURNACES FOR METALLURGICAL, MANUFACTURING AND OTHER PROCESSES	
Steel plants, foundries, forges, etc.	18
Brick, pottery and allied processes	10
Miscellaneous manufacturing, rendering and other processes	1
Total for all services	111

TABLE LXXXVIII. AMOUNT OF SOLID CONSTITUENTS OF SMOKE FROM LOW PRESSURE STEAM AND OTHER STATIONARY HEATING PLANTS, IN TERMS OF FUEL CONSUMED

Test No.	Fuel Consumed in Pounds per Hour		Observed Smoke Density Per Cent Ringelmann Method	Solid Constituents of Smoke							
				In Pounds per Ton of Fuel Consumed				In Per Cent of Fuel Consumed			
	Total	Per Sq. Ft. of Grate Surface		Coarse Cinders	Fine Cinders	Fuel Dust	Total	Coarse Cinders	Fine Cinders	Fuel Dust	Total
1	2	3	4	5	6	7	8	9	10	11	12
				Anthracite Coal							
103	76.0	2.92	0	0	0	2.36	2.36	0	0	0.118	0.118
104	126.5	7.92	0	0	0	3.14	3.14	0	0	0.157	0.157
100	19.7	3.04	0	0	0	3.00	3.00	0	0	0.150	0.150
101	6.1	3.50	0	0	0	3.60	3.60	0	0	0.180	0.180
102	7.7	4.37	0	0	0	3.40	3.40	0	0	0.170	0.170
108	11.6	6.60	0	0	0	2.88	2.88	0	0	0.144	0.144
109	12.0	6.80	0	0	0	1.28	1.28	0	0	0.064	0.064
113	10.0	3.13	0	0	0	1.84	1.84	0	0	0.092	0.092
114	6.4	2.06	0	0	0	0.64	0.64	0	0	0.034	0.034
121	5.9	7.61	0	0	0	1.70	1.70	0	0	0.085	0.085
127	5.0	6.67	0	0	0	9.42	9.42	0	0	0.471	0.471
Average				0	0	2.76	2.76	0	0	0.138	0.138
				Pocahontas Coal							
98	71.0	7.10	1.72	0	1.10	6.90	8.00	0	0.055	0.345	0.400
99	160.7	8.03	0.43	0	0	4.92	4.92	0	0	0.246	0.246
105	583.2	10.79	0.63	0	1.60	6.40	8.00	0	0.080	0.320	0.400
106	624.0	11.54	0.75	0	2.14	8.74	10.88	0	0.107	0.437	0.544
110	33.3	2.72	0	0	0	52.60	52.60	0	0	2.630	2.630
112	93.4	3.11	0	0	0	7.56	7.56	0	0	0.378	0.378
97	72.4	10.34	0	0	1.48	7.72	9.20	0	0.074	0.386	0.460
107	12.9	7.29	0	0	0	12.00	12.00	0	0	0.600	0.600
122	6.0	4.38	2.78	0	0	18.98	18.98	0	0	0.949	0.949
124	4.8	8.74	3.01	0	0	9.42	9.42	0	0	0.471	0.471
Average				0	1.48	8.32	9.80	0	0.074	0.416	0.490
				Bituminous Coal							
117	16.5	21.33	7.78	0	1.10	13.22	14.32	0	0.055	0.661	0.716
118	18.4	23.63	8.32	0	3.56	10.08	13.64	0	0.178	0.504	0.682
119	4.6	5.98	6.05	0	0	28.10	28.10	0	0	1.405	1.405
120	7.5	9.55	3.83	0	1.54	41.14	42.68	0	0.077	2.057	2.134
123	4.8	3.50	3.75	0	1.74	54.62	56.36	0	0.087	2.731	2.818
125	3.7	6.72	12.71	0	0	13.76	13.76	0	0	0.688	0.688
126	8.8	11.38	6.71	0	1.04	27.30	28.34	0	0.052	1.365	1.417
Average				0	1.72	21.70	23.42	0	0.086	1.085	1.171

TABLE LXXXIX. AMOUNT OF SOLID CONSTITUENTS OF SMOKE FROM FURNACES FOR METALLURGICAL, MANUFACTURING AND OTHER PROCESSES, IN TERMS OF FUEL CONSUMED

Test No.	Fuel Consumed in Pounds per Hour		Observed Smoke Density Per Cent Ringelmann Method	Solid Constituents of Smoke							
				In Pounds per Ton of Fuel Consumed				In Per Cent of Fuel Consumed			
	Total	Per Sq. Ft. of Grate Surface		Coarse Cinders	Fine Cinders	Fuel Dust	Total	Coarse Cinders	Fine Cinders	Fuel Dust	Total
1	2	3	4	5	6	7	8	9	10	11	12
Anthracite Coal											
49	362	.....	0	0	6.68	29.28	35.96	0	0.334	1.464	1.798
Average					6.68	29.28	35.96	0	0.334	1.464	1.798
Coke											
43	1,200	95.60	12.53	6.70	51.14	52.80	110.64	0.335	2.557	2.640	5.532
44	1,200	95.60	5.18	4.26	42.16	31.50	77.92	0.213	2.108	1.575	3.896
47	3,800	98.90	5.71	7.68	67.88	53.40	128.96	0.384	3.394	2.670	6.448
59	4,370	.....	48.11	0	16.88	204.34	221.22	0	0.844	10.217	11.061
60	3,925	.....	26.48	0	10.44	143.16	153.60	0	0.522	7.158	7.680
61	4,092	.....	17.00	0	3.80	107.48	111.28	0	0.190	5.374	5.564
62	4,125	.....	7.52	0	13.30	166.28	179.58	0	0.665	8.314	8.979
69	1,537	.....	0.31	0	0.14	0.44	0.58	0	0.007	0.022	0.029
70	1,540	.....	0.05	0	0.04	0.28	0.32	0	0.002	0.014	0.016
71	1,532	.....	0.05	0	0	0.22	0.22	0	0	0.011	0.011
Average				1.52	20.40	105.68	127.60	0.076	1.020	5.284	6.380
Bituminous Coal											
31	1,975	40.00	16.70	0	0	11.96	11.96	0	0	0.598	0.598
32	2,000	40.00	11.30	0	0	23.42	23.42	0	0	1.171	1.171
63	1,320	.....	7.87	0	0	30.38	30.38	0	0	1.519	1.519
64	1,042	.....	3.87	5.36	4.36	22.32	32.04	0.268	0.218	1.116	1.602
67	3,104	.....	1.79	0	0	19.76	19.76	0	0	0.988	0.988
68	3,154	.....	0	0	0	23.66	23.66	0	0	1.183	1.813
Average				0 44	0.36	20.88	21.68	0.022	0.018	1.044	1.084
Pocahontas Coal											
34	730	7.60	6.40	0	0.36	1.38	1.74	0	0.018	0.069	0.087
35	730	7.60	13.33	0	0.54	2.14	2.68	0	0.027	0.107	0.134
36	730	7.60	38.80	1.90	1.58	14.30	17.78	0.095	0.079	0.715	0.889
38	134	5.60	3.79	0	8.52	20.90	29.40	0	0.426	1.045	1.470
41	200	20.00	10.45	2.70	14.28	14.60	31.58	0.135	0.714	0.730	1.579
72	300	6.10	15.48	0	3.40	63.60	67.00	0	0.170	3.180	3.350
75	300	6.10	14.67	0	30.90	399.80	430.70	0	1.545	19.990	21.535
76	1,050	.....	3.94	0	82.72	560.00	642.72	0	4.136	28.000	32.136
77	1,101	.....	4.07	0	135.40	608.20	743.60	0	6.770	30.410	37.180
Average				0.36	47.10	263.74	311.20	0.018	2.355	13.187	15.560
Anthracite Coal											
111	17.9	4.48	0	0	0	4.46	4.46	0	0	0.223	0.223
Average				0	0	4.46	4.46	0	0	0.223	0.223

A complete record of the facts relating to the amount and physical character of the solid constituents of smoke from the stacks of steam vessels and stationary plants, in terms of fuel consumed, as determined by each of the tests referred to, is presented as tables LXXXVI to LXXXIX, inclusive.

105.27 Application of Results of Tests to all Services: Owing to the length of time required in the field to prepare for and conduct each test and to the time required in the laboratory to make analyses, certain tests, originally planned, representing conditions under which only a small amount of certain coals was burned, were omitted. In such cases, results obtained from other tests representing similar conditions were regarded as applicable. The extent of these adjustments is explained in the following:

1. The emission factors determined as a result of tests of locomotives in yard service were considered applicable to locomotives operating in passenger transfer service.

2. The emission factors determined for bituminous coal consumed in through passenger service were considered applicable to the small amount of Pocahontas coal burned in that service.

3. The emission factors determined for anthracite coal burned under strong draft in industrial furnaces were considered applicable to the small amount of anthracite consumed by steam vessels and by high pressure steam stationary power and heating plants, and also to the small amount of coke burned in low pressure steam and other stationary heating plants.

4. The emission factors determined for Pocahontas coal burned by steam vessels were considered applicable to Pocahontas coal burned by furnaces for metallurgical, manufacturing and other processes.

105.28 Amount of Solids in Smoke, in Terms of Fuel Consumed: The emission factors for solids determined as a result of the various smoke tests made in connection with different fuels, including the field tests on locomotives, the locomotive laboratory tests and the smoke sampling tests on steam vessels and stationary plants, together with the emission rates assigned to certain services on the basis of determinations made under similar conditions as described (section 105.27), constitute a complete set of values for each service concerned in the production of smoke in the Area of Investigation. A summary of these results is presented as table XC.

105.29 Relative Standing of Different Services as Producers of Solids in Smoke: From a knowledge of the amount of fuel consumed by different classes of service (chapter 104) and of the emission factors for solids in smoke as hereinbefore set forth (section 105.28), it is possible to determine the relative importance of the different services from the standpoint of the solid constituents of smoke, in terms of fuel consumed. Thus, the total number of tons of fuel consumed in each service multiplied by the emission factor for solids for that service gives a product which represents the total quantity of solids emitted in the smoke produced by the service in question. The ratio of the quantity thus obtained to the sum of such quantities for all services gives a measure of the relative standing of the service in question as a producer of solids in smoke. The results thus obtained are presented, for Zone A as table XCI, for Zone B as table XCII and for Zones A and B combined as table XCIII.

The relative standing of the several services as producers of smoke, on the basis of the total quantity of solids emitted in smoke, is shown graphically by fig. 26.

105.30 Chemical Composition of the Solid Constituents of Smoke: The polluting effects of the solid constituents of smoke are dependent to some extent upon their chemical composition. The presence of hydrocarbons, for instance, is generally more objectionable than the presence of mineral matter or unconsumed carbon. Hydrocarbons constitute a large proportion of the distillates of coal, which become apparent in the atmosphere in the form of soot and readily soil and

TABLE XC. EMISSION FACTORS FOR SOLIDS IN SMOKE, OR THE AMOUNT OF THE SOLID CONSTITUENTS OF SMOKE, IN TERMS OF FUEL CONSUMED. ALL SERVICES

Service	Kind of Fuel	Solid Constituents of Smoke							
		In Pounds per Ton of Fuel Consumed				In Per Cent of Fuel Consumed			
		Coarse Cinders	Fine Cinders	Fuel Dust	Total	Coarse Cinders	Fine Cinders	Fuel Dust	Total
1	2	3	4	5	6	7	8	9	10
Steam Locomotives:									
Yard	Poc.	1.30	9.72	24.54	35.56	0.065	0.486	1.227	1.778
	Bit.	0.76	3.42	5.24	9.42	0.038	0.171	0.262	0.471
Road freight	Bit.	11.30	34.68	6.86	52.84	0.565	1.734	0.343	2.642
Freight transfer	Poc.	1.84	7.92	19.64	29.40	0.092	0.396	0.982	1.470
	Bit.	0.62	2.16	4.46	7.24	0.031	0.108	0.223	0.362
Passenger transfer	Poc.	* 1.30	* 9.72	*24.54	*35.56	*0.065	*0.486	*1.227	*1.778
	Bit.	* 0.76	* 3.42	* 5.24	* 9.42	*0.038	*0.171	*0.262	*0.471
Through passenger	Poc.	*15.08	*39.40	* 7.84	*62.32	*0.754	*1.970	*0.392	*3.116
	Bit.	15.08	39.40	7.84	62.32	0.754	1.970	0.392	3.116
Suburban passenger	Bit.	20.54	47.42	9.26	77.32	1.032	2.371	0.463	3.866
Locomotive terminals	Bit.	* 0.76	* 3.42	* 5.24	* 9.42	*0.038	*0.171	*0.262	*0.471
Steam Vessels	Anth.	* 0	* 0	* 4.46	* 4.46	* 0	* 0	*0.223	*0.223
	Poc.	0	8.02	17.78	25.80	0	0.401	0.889	1.290
	Bit.	1.70	12.14	10.60	24.44	0.085	0.607	0.530	1.222
High Pressure Steam Stationary Power and Heating Plants	Anth.	* 0	* 0	* 4.46	* 4.46	* 0	* 0	*0.223	*0.223
	Coke	* 0	* 0	* 4.46	* 4.46	* 0	* 0	*0.223	*0.223
	Poc.	0	2.26	10.72	12.98	0	0.113	0.536	0.649
	Bit.	0.06	5.32	10.84	16.22	0.003	0.266	0.542	0.811
Low Pressure Steam and Other Stationary Heating Plants	Anth.	0	0	2.76	2.76	0	0	0.138	0.138
	Coke	* 0	* 0	* 4.46	* 4.46	* 0	* 0	*0.223	*0.223
	Poc.	0	1.48	8.32	9.80	0	0.074	0.416	0.490
	Bit.	0	1.72	21.70	23 42	0	0.086	1.085	1 171
Gas and Coke Plants	Anth.	No tests made							
	Coke								
	Poc.								
	Bit.								
Furnaces for Metallurgical, Manufacturing and Other Processes: Steel plants, foundries, forges and other allied processes	Anth.	0	6.68	29.28	35.96	0	0.334	1.464	1.798
	Coke	1.52	20.40	105.68	127.60	0.076	1.020	5.284	6.380
	Poc.	* 0	* 8.02	*17.78	*25.80	* 0	*0.401	*0.889	*1.290
	Bit.	0.44	0.36	20.88	21.68	0.022	0.018	1.044	1.084
Brick, pottery and other allied processes	Coke	* 0	* 6.68	*29.28	*35.96	* 0	*0.334	*1.464	*1.798
	Poc.	* 0	* 8.02	*17.78	*25.80	* 0	*0.401	*0.889	*1 290
	Bit.	0.36	47 10	263.74	311 20	0 018	2.355	13.187	15 560
Miscellaneous manufacturing, rendering and other processes	Anth.	0	0	4.46	4 46	0	0	0.223	0 223
	Coke	* 0	* 6.68	*29.28	*35.96	* 0	*0.334	*1.464	*1.798
	Poc.	* 0	* 8 02	*17 78	*25 80	* 0	*0 401	*0.889	*1 290
	Bit.	* 0 44	* 0 36	*20 88	*21 68	*0 022	*0 018	*1 044	*1.084

* Values adapted from determinations made under similar conditions.

blacken all materials with which they come in contact. Soot is volitant and is easily transported by air currents. Mineral matter and unconsumed carbon particles are less prolific sources of dirt because they lack both the coloring matter and the adhesive properties of soot, and it is probable that a large proportion of these substances settle to the ground near the point of emission. Any

TABLE XCI. AMOUNT OF SOLIDS EMITTED IN SMOKE FROM EACH SERVICE AND RELATIVE STANDING OF SERVICES
ZONE A

Service	Fuel Consumed		Solids in Smoke		
	Kind	Tons	In Per Cent of Fuel Consumed	Tons	Per Cent of Total
1	2	3	4	5	6
Steam Locomotives:					
Yard	Poc.	23,049	1.778	410	0.14
	Bit.	1,026,467	0.471	4,835	1.59
Road freight	Bit.	136,115	2.642	3,596	1.18
Freight transfer	Poc.	2,996	1.470	44	0.01
	Bit.	351,806	0.362	1,274	0.42
Passenger transfer	Poc.	885	1.778	16	0.01
	Bit.	20,485	0.471	96	0.03
Through passenger	Poc.	2,441	3.116	76	0.02
	Bit.	174,320	3.116	5,432	1.78
Suburban passenger	Bit.	155,327	3.866	6,005	1.97
Locomotive terminals	Bit.	205.153	0.471	966	0.32
Totals		2,099,044	1.084	22,750	7.47
Steam Vessels:					
Tugs and lighters	Anth.	112	0.223	†	*
	Poc.	3,748	1.290	48	0.02
	Bit.	31,293	1.222	382	0.12
River barges, dredges, etc	Poc.	1,186	1.290	15	0.01
	Bit.	9,339	1.222	114	0.04
Lake steamers and barges	Bit.	35,697	1.222	436	0.14
Totals		81.375	1.223	995	0.33
High Pressure Steam Stationary Power and Heating Plants: Public service, municipal, steam railroad, office buildings, hotels, schools and manufacturing	Anth.	5,291	0.223	12	*
	Coke	2,121	0.223	5	*
	Poc.	262,196	0.649	1.702	0.56
	Bit.	7,046,649	0.811	57,148	18.78
Totals		7,316,257	0.805	58,867	19.34
Low Pressure Steam and Other Stationary Heating Plants: Buildings, apartments and residences	Anth.	1,577,761	0.138	2,177	0.71
	Coke	41,181	0.223	92	0.03
	Poc.	849,185	0.490	4,161	1.37
	Bit.	1,686,619	1.171	19,750	6.49
Totals		4.154,746	0.630	26,180	8.60
Gas and Coke Plants (exclusive of boiler power plants): Public service	Anth.	5,882	No tests made		
	Coke	133,643			
Other service	Anth.	245			
	Poc.	2,366			
	Bit.	92,415			
Totals		234,551			
Furnaces for Metallurgical, Manufacturing and Other Processes (exclusive of boiler power plants): Steel plants, foundries, forges and allied processes	Anth.	31,442	1.798	565	0.19
	Coke	2,909,360	6.380	185,617	60.98
	Poc.	26,368	1.290	340	0.11
	Bit.	651,187	1.084	7,059	2.32
Totals		3,618,357	5.350	193,581	63.60
Brick, pottery and allied processes	Coke	206	1.798	4	*
	Poc.	0	0	0	*
	Bit.	8,165	15.560	1,270	0.42
Totals		8,371	15.219	1,274	0.42
Miscellaneous manufacturing, rendering and other processes	Anth.	12,269	0.223	28	0.01
	Coke	12,791	1.798	230	0.07
	Poc.	322	1.290	4	*
	Bit.	44,440	1.084	482	0.16
Totals		69,822	1.066	744	0.24
Sub-Totals		3,696,550	5.291	195,599	64.26
Grand Totals		17,582,523	1.731	304,391	100.00

* Less than 0.005 per cent.
† Less than 0.5 ton.

TABLE XCII. AMOUNT OF SOLIDS EMITTED IN SMOKE FROM EACH SERVICE AND RELATIVE STANDING OF SERVICES
ZONE B

Service	Fuel Consumed		Solids in Smoke		
	Kind	Tons	In Per Cent of Fuel Consumed	Tons	Per Cent of Total
1	2	3	4	5	6
Steam Locomotives:					
Yard	Poc.	0	0	0	0
	Bit.	313,987	0.471	1,479	2.76
Road freight	Bit.	122,672	2.642	3,241	6.05
Freight transfer	Poc.	0	0	0	0
	Bit.	124,936	0.362	452	0.84
Passenger transfer	Poc.	0	0	0	0
	Bit.	175	0.471	1	*
Through passenger	Poc.	0	0	0	0
	Bit.	63,527	3.116	1,979	3.69
Suburban passenger	Bit.	36,045	3.866	1,394	2.60
Locomotive terminals	Bit.	55,014	0.471	259	0.49
Totals		716,356	1.229	8,805	16.43
Steam Vessels:					
Tugs and lighters	Anth.	12	0.223	†	*
	Poc.	234	1.290	3	0.01
	Bit.	8,579	1.222	105	0.20
River barges, dredges, etc	Poc.	82	1.290	1	*
	Bit.	1,132	1.222	14	0.02
Lake steamers and barges	Bit.	954	1.222	12	0.02
Totals		10,993	1.228	135	0.25
High Pressure Steam Stationary Power and Heating Plants: Public service, municipal, steam railroad, office buildings, hotels, schools and manufacturing	Anth.	0	0	0	0
	Coke	423	0.223	1	*
	Poc	14,824	0.649	96	0.18
	Bit.	1,815,830	0.811	14,726	27.47
Totals		1,831,077	0.810	14,823	27.65
Low Pressure Steam and Other Stationary Heating Plants: Buildings, apartments and residences	Anth.	193,511	0.138	267	0.50
	Coke	13,896	0.223	31	0.06
	Poc.	40,543	0.490	199	0.37
	Bit.	244,214	1.171	2,860	5.33
Totals		492,164	0.682	3,357	6.26
Gas and Coke Plants (exclusive of boiler power plants): Public service	Anth.	0	No tests made		
	Coke	18,159			
Other service	Anth.	0			
	Poc.	0			
	Bit.	1,157			
Totals		19,316			
Furnaces for Metallurgical, Manufacturing and Other Processes (exclusive of boiler power plants): Steel plants, foundries, forges and allied processes	Anth.	529	1.798	10	0.02
	Coke	301,373	6.380	19,228	35.87
	Poc.	162	1.290	2	*
	Bit.	218,905	1.084	2,373	4.43
Totals		520,969	4.149	21,613	40.32
Brick, pottery and allied processes	Coke	1,633	1.798	29	0.05
	Poc.	200	1.290	3	*
	Bit.	30,888	15.560	4,806	8.97
Totals		32,721	14.786	4,838	9.02
Miscellaneous manufacturing, rendering and other processes	Anth.	104	0.223	†	*
	Coke	967	1.798	18	0.03
	Poc.	0	0	0	0
	Bit.	1,696	1.084	18	0.04
Totals		2,767	1.301	36	0.07
Sub-Totals		556,457	4.760	26,487	49.41
Grand Totals		3,626,363	1.478	53,607	100.00

* Less than 0.005 per cent.
† Less than 0.5 ton.

FIG. 26. RELATIVE STANDING OF THE SEVERAL SERVICES AS PRODUCERS OF SOLIDS EMITTED IN SMOKE

[Facing p. 156]

service, therefore, the smoke of which possesses a high content of hydrocarbon, constitutes a more objectionable source of atmospheric pollution than one the smoke of which shows a low content of such distillates. Determination of the amount of hydrocarbons (tar), combustible solids (carbon), mineral matter (ash), and sulphur present in the smoke discharges of each class of service, was made by chemical analyses of numerous samples of the solid materials collected in connection with the smoke sampling tests made upon locomotives, steam vessels and stationary plants, as already described.

TABLE XCIII. AMOUNT OF SOLIDS EMITTED IN SMOKE FROM EACH SERVICE AND RELATIVE STANDING OF SERVICES ZONES A AND B

Service	Fuel Consumed		Solids in Smoke		
	Kind	Tons	In Per Cent of Fuel Consumed	Tons	Per Cent of Total
1	2	3	4	5	6
Steam Locomotives:					
Yard	Poc.	23,049	1.778	410	0.11
	Bit.	1,340,454	0.471	6,314	1.77
Road freight	Bit.	258,787	2.642	6,837	1.91
Freight transfer	Poc.	2,996	1.470	44	0.01
	Bit.	476,742	0.362	1,726	0.48
Passenger transfer	Poc.	885	1.778	16	*
	Bit.	20,660	0.471	97	0.03
Through passenger	Poc.	2,441	3.116	76	0.02
	Bit.	237,847	3.116	7,411	2.07
Suburban passenger	Bit.	191,372	3.866	7,399	2.07
Locomotive terminals	Bit.	260.167	0.471	1,225	0.34
Totals		2,815,400	1.121	31,555	8.81
Steam Vessels:					
Tugs and lighters	Anth.	124	0.223	†	*
	Poc.	3,982	1.290	51	0.01
	Bit.	39,872	1.222	487	0.14
River barges, dredges, etc.	Poc.	1,268	1.290	16	*
	Bit.	10,471	1.222	128	0.04
Lake steamers and barges	Bit.	36,651	1.222	448	0.13
Totals		92,368	1.223	1,130	0.32
High Pressure Steam Stationary Power and Heating Plants: Public service, municipal, steam railroad, office buildings, hotels, schools and manufacturing	Anth.	5,291	0.223	12	*
	Coke	2,544	0.223	6	*
	Poc.	277,020	0.649	1,798	0.50
	Bit.	8,862,479	0.811	71,874	20.08
Totals		9,147,334	0.806	73,690	20.58
Low Pressure Steam and Other Stationary Heating Plants: Buildings, apartments and residences	Anth.	1,771,272	0.138	2,444	0.68
	Coke	55,077	0.223	123	0.03
	Poc.	889,728	0.490	4,360	1.22
	Bit.	1,930,833	1.171	22,610	6.32
Totals		4,646,910	0.636	29,537	8.25
Gas and Coke Plants (exclusive of boiler power plants):					
Public service	Anth.	5,882	No tests made		
	Coke	151,802			
Other service	Anth.	245			
	Poc.	2,366			
	Bit.	93,572			
Totals		253,867			
Furnaces for Metallurgical, Manufacturing and Other Processes (exclusive of boiler power plants):					
Steel plants, foundries, forges and allied processes	Anth.	31,971	1.798	575	0.16
	Coke	3,210,733	6.380	204,845	57.22
	Poc.	26,530	1.290	342	0.10
	Bit.	870,092	1 084	9,432	2.63
Totals		4,139,326	5.199	215,194	60.11
Brick, pottery and allied processes	Coke	1,839	1.798	33	0.01
	Poc.	200	1.290	3	*
	Bit.	39,053	15.560	6,076	1.70
Totals		41,092	14.874	6,112	1.71
Miscellaneous manufacturing, rendering and other processes	Anth.	12,373	0.223	28	0.01
	Coke	13,758	1.798	248	0.07
	Poc.	322	1.290	4	*
	Bit.	46.136	1.084	500	0.14
Totals		72,589	1.075	780	0.22
Sub-Totals		4,253,007	5.222	222,086	62.04
Grand Totals		21,208,886	1.688	357,998	100.00

* Less than 0.005 per cent.

† Less than 0.5 ton.

The samples of solid materials taken from the cinder arresters employed in the case of locomotive tests, and from the filters employed in the case of tests on steam vessels and stationary plants, were analyzed, essentially the same method of analysis being employed in both cases. In the case of the solids from locomotive smoke it was necessary to analyze only representative samples of the materials collected, while in that of the solids contained in the smoke of other services it was necessary to analyze both the free samples collected and the filters themselves, since a portion of the solids became entrained in the fiber of the filters. The exact procedure of conducting a chemical analysis of the contents of filters may be described as follows:

Initially the filters were carefully weighed and their weights were recorded preparatory to each test. The percentage of ash contained in the materials of which the filters themselves were made was also determined by experiments in which a number of the prepared filters were ignited. At the conclusion of a test the filters and their contents were weighed and placed in a Soxhlet extraction tube and treated with ether, the process serving to extract the tarry matter or hydrocarbons. The ether was then reclaimed and the residue, or tarry matter, was weighed.

After this determination the filters and their contents were dried and again weighed. The difference between this weight and that of the dry filter before the test, added to the weight of the tarry matter extracted, served to give the total weight of the solid constituents of the smoke samples. For further analysis, the sample of the solid materials collected, not including the filter itself, was divided into two equal parts, one being used for the sulphur determination and the other for the determination of mineral matter and unconsumed carbon. The portion selected for the sulphur determination was mixed with sodium carbonate and magnesium oxid and fused in a platinum crucible. The fused mass was then treated with hot water to dissolve the sulphur compounds, and filtered. The filtrate was treated with bromine, the excess of which was boiled off, and hydrochloric acid and barium chlorid were added to precipitate the sulphur as barium sulphate. The precipitate was then treated in the usual manner to determine the sulphur. The weight of the sulphur thus obtained, divided by the weight of the fused sample and multiplied by the difference in weight between the total solid constituents of the smoke and the tar or hydrocarbons as previously determined, was recorded as the weight of the sulphur.

For the determination of mineral matter or ash, the second portion of the sample of solids was incinerated and weighed. This weight multiplied by two served to give the total weight of the ash in the sample. The weight of the ash in the filter, as determined initially, was then deducted from the weight of the ash, as determined by incinerating the filter after the test, the difference being taken as the weight of the ash resulting from the products of combustion which became entrained in the fiber of the filter. This value added to the weight of the ash in the sample of solids gave the total weight of ash contained in the products of combustion intercepted by the filter. The sum of the weight of the hydrocarbons, sulphur and mineral matter subtracted from the total weight of the solids contained in the sample under analysis, served to disclose the weight of the combustible solids or unconsumed carbon present in the solid constituents of smoke.

Values for each chemical constituent expressed in its per cent of total solids as disclosed by the analyses described, when applied to samples of solids collected in connection with the tests conducted in the various classes of service, are presented as table XCIV.

The total amounts of the different kinds of solid materials, subdivided according to both physical and chemical classification, were determined by applying the values hereinbefore set forth to the total quantity of fuel consumed in each service or to the total quantity of solid materials emitted in the smoke of each service. These values, expressed in tons of solids emitted during the year 1912 by each of the different classes of service in Zone A, Zone B, and Zones A and B combined, are presented as tables XCV, XCVI, and XCVII.

TABLE XCIV. CHEMICAL COMPOSITION OF THE SOLID CONSTITUENTS OF SMOKE

Service	Kind of Fuel	Per Cent of Total Solids				
		Hydro-Carbons (Tar)	Combustible Solids (Carbon)	Mineral Matter (Ash)	Sulphur	Total
1	2	3	4	5	6	7
Steam Locomotives:						
Yard	Poc.	0.28	52.25	46.29	1.18	100.00
	Bit.	0.64	39.28	57.32	2.76	100.00
Road freight	Bit.	0.64	60.33	36.49	2.54	100.00
Freight transfer	Poc.	0.41	63.33	35.10	1.16	100.00
	Bit.	0.55	43.65	53.59	2.21	100.00
Through passenger	Bit.	0.45	61.33	35.85	2.37	100.00
Suburban passenger	Bit.	0.39	65.34	31.92	2.35	100.00
Steam Vessels	Poc.	3.88	44.80	50.62	0.70	100.00
	Bit.	2.62	51.23	45.50	0.65	100.00
High Pressure Plants	Poc.	3.08	41.45	52.39	3.08	100.00
	Bit.	4.19	32.80	59.93	3.08	100.00
Low Pressure Plants	Anth.	0.73	31.88	67.39	0 00	100.00
	Poc.	11.43	54.90	33.47	0.20	100.00
	Bit.	31.43	44.06	22.12	2.39	100.00
Gas and Coke Plants	No tests made					
Special Furnaces—steel plants, foundries, etc.	Anth.	1.50	21.80	75.42	1.28	100.00
	Coke	0.56	10.86	87.95	0.63	100.00
	Bit.	18.91	45.20	35.33	0.56	100.00
Special Furnaces—brick and pottery plants	Bit.	0.24	8.97	88.07	2.72	100.00
Special Furnaces—miscellaneous plants	Anth.	30.04	37.67	32.29	0 00	100.00

INCIDENTAL FACTS CONCERNING SOLIDS IN SMOKE

105.31 Solids of Non-Fuel Origin in Smoke: The preceding sections serve to show the extent to which the different fuel consuming services contribute to the dust content of the atmosphere. The conclusions which are therein set forth satisfy the primary purpose of the Committee's investigation. These having been presented, it will be of interest to extend the discussion to a brief consideration of certain incidental facts with reference to solids in smoke.

Attention has already been directed to the fact that not all of the solids in smoke are of fuel origin (section 105.21), though, for purposes thus far set forth, it has been assumed that all solid matter passing out of chimneys and smoke-stacks with the products of combustion may be regarded as solid constituents of smoke. Since the purpose of the investigation is to determine the relative contributions of different fuel consuming services to the total quantity of dust in the atmosphere, this assumption is not misleading, and it has the advantage of supplying a definite basis upon which conclusions may be established. Its effect, however, has been to emphasize the importance of certain metallurgical and other industrial fires which send out with the products

TABLE XCV. TOTAL AMOUNTS OF SOLID CONSTITUENTS OF SMOKE OF DIFFERENT SERVICES IN ZONE A FOR THE YEAR 1912

Service	Kind of Fuel	Emission Factors Total Solids in Per Cent of Fuel Burned	Solid Constituents of Smoke—Tons							Total Weight of Solids
			By Physical Analyses			By Chemical Analyses				
			Coarse Cinders	Fine Cinders	Fuel Dust	Hydro-Carbons (Tar)	Combustible Solids (Carbon)	Mineral Matter (Ash)	Sulphur	
1	2	3	4	5	6	7	8	9	10	11
Steam Locomotives:										
Yard	Poc.	1.778	15.0	112.0	283.0	1.1	214.3	189.8	4.8	410
	Bit.	0.471	390.2	1,755.4	2,689.4	30.9	1,899.2	2,771.5	133.4	4,835
Road freight	Bit.	2.642	769.0	2,360.1	466.9	23.0	2,109.5	1,312.2	91.3	3,596
Freight transfer	Poc.	1.470	2.8	11.9	29.3	0.2	27.9	15.4	0.5	44
	Bit.	0.362	109.6	380.0	781.4	7.0	556.1	682.7	28.2	1,274
Passenger transfer	Poc.	1.778	0.6	4.4	11.0	*	8.4	7.4	0.2	16
	Bit.	0.471	7.8	35.0	56.2	0.6	37.7	55.0	2.7	96
Through passenger	Poc.	3.116	18.4	48.0	9.6	0.3	46.7	27.2	1.8	76
	Bit.	3.116	1,314.5	3,434.2	683.3	24.4	3,331.5	1,947.4	128.7	5,432
Suburban passenger	Bit.	3.866	1,603.0	3,682.8	719.2	23.4	3,923.7	1,916.8	141.1	6,005
Locomotive terminals	Bit.	0.471	78.0	350.8	537.2	6.2	379.4	553.7	26.7	966
Totals	....	.....	4,308.9	12,174.6	6,266.5	117.1	12,594.4	9,479.1	559.4	22,750
Steam Vessels:										
Tugs and lighters	Anth.	0.223	0	0	*	*	*	*	*	*
	Poc.	1.290	0	15.0	33.0	1.9	21.5	24.3	0.3	48
	Bit.	1.222	26.6	189.7	165.7	10.0	195.7	173.8	2.5	382
River barges, dredges, etc.	Poc.	1.290	0	4.8	10.2	0.6	6.7	7.6	0.1	15
	Bit.	1.222	7.9	56.6	49.5	3.0	58.4	51.9	0.7	114
Lake steamers and barges	Bit.	1.222	30.3	216.5	189.2	11.4	223.4	198.4	2.8	436
Totals	....	.....	64.8	482.6	447.6	26.9	505.7	456.0	6.4	995
High Pressure Steam Stationary Power and Heating Plants: Public service, municipal, steam railroad, office buildings, hotels, schools and manufacturing	Anth.	0.223	0	0	12.0	3.6	4.5	3.9	*	12
	Coke	0.223	0	0	5.0	1.4	1.9	1.7	*	5
	Poc.	0.649	0	296.3	1,405.7	52.4	705.5	891.7	52.4	1,702
	Bit.	0.811	211.4	18,744.1	38,192.5	2,394.5	18,744.5	34,248.8	1,760.2	57,148
Totals	....	.....	211.4	19,040.4	39,615.2	2,451.9	19,456.4	35,146.1	1,812.6	58,867
Low Pressure Steam and Other Stationary Heating Plants: Buildings, apartments and residences	Anth.	0.138	0	0	2,177.0	15.9	694.0	1,467.1	*	2,177
	Coke	0.223	0	0	92.0	27.6	34.7	29.7	*	92
	Poc.	0.490	0	628.4	3,532.6	475.6	2,284.4	1,392.7	8.3	4,161
	Bit.	1.171	0	1,450.5	18,299.5	6,207.4	8,701.9	4,368.7	472.0	19,750
Totals	....	.....	0	2,078.9	24,101.1	6,726.5	11,715.0	7,258.2	480.3	26,180
Gas and Coke Plants (exclusive of boiler power plants)	Anth. Coke Poc. Bit.	No tests made								
Furnaces for Metallurgical, Manufacturing and Other Processes (exclusive of boiler power plants): Steel plants, foundries, forges and allied processes	Anth.	1.798	0	105.0	460.0	8.5	123.2	426.1	7.2	565
	Coke	6.380	2,211.1	29,675.3	153,730.6	1,039.5	20,158.0	163,250.1	1,169.4	185,617
	Poc.	1.290	0	105.7	234.3	13.2	152.3	172.1	2.4	340
	Bit.	1.084	143.3	117.2	6,798.5	1,334.9	3,190.7	2,493.9	39.5	7,059
Totals	....	.....	2,354.4	30,003.2	161,223.4	2,396.1	23,624.2	166,342.2	1,218.5	193,581
Brick, pottery and allied processes	Coke	1.798	0	1.0	3.0	0.1	0.8	3.0	0.1	4
	Poc.	1.290	0	0	0	0	0	0	0	0
	Bit.	15.560	1.5	192.0	1,076.5	3.0	113.9	1,118.6	34.5	1,270
Totals	....	.....	1.5	193.0	1,079.5	3.1	114.7	1,121.6	34.6	1,274
Miscellaneous manufacturing, rendering and other processes	Anth.	0.223	0	0	28.0	8.4	10.6	9.0	*	28
	Coke	1.798	0	42.7	187.3	3.5	50.1	173.5	2.9	230
	Poc.	1.290	0	1.3	2.7	0.2	1.8	2.0	*	4
	Bit.	1.084	9.8	8.0	464.2	91.1	217.9	170.3	2.7	482
Totals	....	.....	9.8	52.0	682.2	103.2	280.4	354.8	5.6	744
Grand Totals	....	.....	6,950.8	64,024.7	233,415.5	11,824.8	68,290.8	220,158.0	4,117.4	304,391

* Less than 0.05 ton.

of combustion a heavy lading of metallic or mineral dust. Fires which are sustained by coke and by fuel gas, as well as those which are sustained by coal, may, upon this basis, be prolific producers of dust.

With this understanding of the character of solids in smoke, it is obvious that the elimination of solid fuels from the Area of Investigation would not in itself suffice to eliminate the solid constituents of smoke. In this case, however, the dust discharges in Chicago would be strongly localized, chiefly in the southern portion of the city.

From the facts of record it is possible to formulate an estimate of the amount of solids in the smoke of the city of Chicago which are not of fuel origin. Thus, it may be assumed that the solids in smoke arising from the high pressure steam boiler service of the city are entirely of fuel origin, and the relation of the solids in the smoke of such fires to the weight of fuel burned has been determined (section 105.26). The solids thus determined are made up in part of combustible material and in part of non-combustible material, and the relation between the two has been established (section 105.30).

In the study of the solids in smoke from metallurgical fires, similar information has been obtained; that is, the amounts of combustible and non-combustible solids in the smoke have been found. If it is assumed that the non-combustible

TABLE XCVI. TOTAL AMOUNTS OF SOLID CONSTITUENTS OF SMOKE OF DIFFERENT SERVICES IN ZONE B FOR THE YEAR 1912

Service	Kind of Fuel	Emission Factors Total Solids In Per Cent of Fuel Burned	Solid Constituents of Smoke—Tons							Total Weight of Solids
			By Physical Analyses			By Chemical Analyses				
			Coarse Cinders	Fine Cinders	Fuel Dust	Hydro-Carbons (Tar)	Combustible Solids (Carbon)	Mineral Matter (Ash)	Sulphur	
1	2	3	4	5	6	7	8	9	10	11
Steam Locomotives:										
Yard	Poc.	1.778	0	0	0	0	0	0	0	0
	Bit.	0.471	119.3	536.9	822.8	9.5	580.9	847.8	40.8	1,479
Road freight	Bit.	2.642	693.1	2,127.1	420.8	20.7	1,955.4	1,182.6	82.3	3,241
Freight transfer	Poc.	1.470	0	0	0	0	0	0	0	0
	Bit.	0.362	38.7	134.9	278.4	2.5	197.3	242.2	10.0	452
Passenger transfer	Poc.	1.778	0	0	0	0	0	0	0	0
	Bit.	0.471	0.1	0.4	0.5	*	0.4	0.6	*	1
Through passenger	Poc.	3.116	0	0	0	0	0	0	0	0
	Bit.	3.116	478.9	1,251.2	248.9	8.9	1,213.7	709.5	46.9	1,979
Suburban passenger	Bit.	3.866	372.0	855.0	167.0	5.4	910.8	445.0	32.8	1,394
Locomotive terminals	Bit.	0.471	20.9	94.0	144.1	1.7	101.7	148.5	7.1	259
Totals	....	.....	1,723.0	4,999.5	2,082.5	48.7	4,960.2	3,576.2	219.9	8,805
Steam Vessels:	Anth.	0.223	0	0	*	*	*	*	*	*
Tugs and lighters	Poc.	1.290	0	0.9	2.1	0.1	1.4	1.5	*	3
	Bit.	1.222	7.3	52.2	45.5	2.8	53.8	47.8	0.6	105
River barges, dredges, etc.	Poc.	1.290	0	0.3	0.7	*	*	0.5	*	1
	Bit.	1.222	1.0	6.9	6.1	0.4	7.2	6.3	0.1	14
Lake steamers and barges	Bit.	1.222	0.9	5.9	5.2	0.3	6.1	5.5	0.1	12
Totals	....	.....	9.2	66.2	59.6	3.6	69.0	61.6	0.8	135
High Pressure Steam Stationary Power and Heating Plants: Public service, municipal, steam railroad, office buildings, hotels, schools and manufacturing	Anth.	0.223	0	0	0	0	0	0	0	0
	Coke	0.223	0	0	1.0	0.3	0.4	0.3	*	1
	Poc.	0.649	0	16.7	79.3	3.0	39.7	50.3	3.0	96
	Bit	0.811	54.4	4,830.0	9,841.6	617.0	4,830.1	8,825.3	453.6	14,726
Totals	....	.....	54.4	4,846.7	9,921.9	620.3	4,870.2	8,875.9	456.6	14,823
Low Pressure Steam and Other Stationary Heating Plants: Buildings, apartments and residences	Anth.	0.138	0	0	267.0	1.9	85.2	179.9	*	267
	Coke	0.223	0	0	31.0	9.3	11.7	10.0	*	31
	Poc.	0.490	0	30.0	169.0	22.7	109.3	66.6	0.4	199
	Bit.	1.171	0	210.0	2,650.0	898.9	1,260.1	632.6	68.4	2,860
Totals	....	.....	0	240.0	3,117.0	932.8	1,466.3	889.1	68.8	3,357
Gas and Coke Plants (exclusive of boiler power plants)	Anth. Coke Poc. Bit.	No tests made								
Furnaces for Metallurgical, Manufacturing and Other Processes (exclusive of boiler power plants):										
Steel plants, foundries, forges and allied processes	Anth.	1.798	0	2.0	8.0	0.2	2.2	7.5	0.1	10
	Coke	6.380	229.0	3,074.0	15,925.0	107.7	2,088.2	16,911.0	121.1	19,228
	Poc.	1.290	0	0.6	1.4	0.1	0.9	1.0	*	2
	Bit.	1.084	48.2	39.4	2,285.4	448.7	1,072.6	838.4	13.3	2,373
Totals	....	.....	277.2	3,116.0	18,219.8	556.7	3,163.9	17,757.9	134.5	21,613
Brick, pottery and allied processes	Coke	1.798	0	5.4	23.6	0.4	6.3	21.9	0.4	29
	Poc.	1.290	0	1.0	2.0	0.1	1.4	1.5	*	3
	Bit.	15.560	5.5	727.4	4,073.1	11.5	431.1	4,232.6	130.8	4,806
Totals	....	.....	5.5	733.8	4,098.7	12.0	438.8	4,256.0	131.2	4,838
Miscellaneous manufacturing, rendering and other processes	Anth.		0	0	*	*	*	*	*	*
	Coke	0 223	0	3.4	14 6	0.3	3.9	13.6	0.2	18
	Poc.	1.798	0	0	0	0	0	0	0	0
	Bit.	1 290	0.3	0.3	17.4	3.4	8.1	6.4	0.1	18
Totals	....	1.084	0.3	3.7	32.0	3.7	12.0	20.0	0.3	36
Grand Totals	....	.....	2,069.6	14,005.9	37,531.5	2,177.8	14,980.4	35,436.7	1,012.1	53,607

* Less than 0.05 ton.

solids of fuel origin in smoke of metallurgical furnaces bear the same relation to the combustible solids as the non-combustible solids of fuel origin in high pressure steam boiler plants bear to the combustible solids, it is possible to account for the total solids in the smoke of metallurgical furnaces which are of fuel origin. The remainder of the solids in the smoke of such furnaces must be of non-fuel origin.

An application of this process to the facts of record gives results showing that, in the aggregate, the amount of non-fuel dust in smoke from metallurgical and other industrial fires is approximately 41 per cent of the total amount of solids emitted by all fires in the city of Chicago. A further interpretation of this fact is presented in the following:

		TONS PER ANNUM
Total solid constituents of smoke from all fuel consuming services		304,391
Non-fuel solid constituents of smoke from steel plants, foundries, forges and allied processes	123,955	
Non-fuel solid constituents of smoke from brick and pottery plants and allied processes	923	
Total solid constituents of smoke of non-fuel origin	124,878	
Total solid constituents of smoke of fuel origin		179,513

105.32 Solids in Smoke as Influenced by Furnace Conditions: The amount and character of the solid constituents of smoke, so far as they are of fuel origin, are functions of furnace condi-

TABLE XCVII. TOTAL AMOUNTS OF SOLID CONSTITUENTS OF SMOKE OF DIFFERENT SERVICES IN ZONES A AND B FOR THE YEAR 1912

Service	Kind of Fuel	Emission Factors Total Solids in Per Cent of Fuel Burned	Solid Constituents of Smoke—Tons							Total Weight of Solids
			By Physical Analyses			By Chemical Analyses				
			Coarse Cinders	Fine Cinders	Fuel Dust	Hydro-Carbons (Tar)	Combustible Solids (Carbon)	Mineral Matter (Ash)	Sulphur	
1	2	3	4	5	6	7	8	9	10	11
Steam Locomotives:										
Yard	Poc.	1.778	15.0	112.0	283.0	1.1	214.3	189.8	4.8	410
	Bit.	0.471	509.5	2,292.3	3,512.2	40.4	2,480.1	3,619.3	174.2	6,314
Road freight	Bit.	2.642	1,462.1	4,487.2	887.7	43.7	4,124.9	2,494.8	173.6	6,837
Freight transfer	Poc.	1.470	2.8	11.9	29.3	0.2	27.9	15.4	0.5	44
	Bit.	0.362	148.3	514.9	1,062.8	9.5	753.4	921.9	38.2	1,726
Passenger transfer	Poc.	1.778	0.6	4.4	11.0	*	8.4	7.4	0.2	16
	Bit.	0.471	7.9	35.4	53.7	0.6	38.1	55.6	2.7	97
Through passenger	Poc.	3.116	18.4	48.0	9.6	0.3	46.7	27.2	1.8	76
	Bit.	3.116	1,793.4	4,685.4	932.2	33.3	4,545.2	2,656.9	175.6	7,411
Suburban passenger	Bit.	3.866	1,975.0	4,537.8	886.2	28.8	4,834.5	2,361.8	173.9	7,309
Locomotive terminals	Bit.	0.471	98.9	444.8	681.3	7.9	481.1	702.2	33.8	1,225
Totals	....	.....	6,031.9	17,174.1	8,349.0	165.8	17,554.6	13,055.3	779.3	31,555
Steam Vessels:										
Tugs and Lighters	Anth.	0.223	0	0	*	*	*	*	*	*
	Poc.	1.290	0	15.9	35.1	2.0	22.9	25.8	0.3	51
	Bit.	1.222	33.9	241.9	211.2	12.8	249.5	221.6	3.1	487
River barges, dredges, etc.	Poc.	1.290	0	5.1	10.9	0.6	7.2	8.1	0.1	16
	Bit.	1.222	8.9	63.5	55.6	3.4	65.6	58.2	0.8	128
Lake steamers and barges	Bit.	1.222	31.2	222.4	194.4	11.7	229.5	203.9	2.9	448
Totals	....	.....	74.0	548.8	507.2	30.5	574.7	517.6	7.2	1,130
High Pressure Steam Stationary Power and Heating Plants: Public service, municipal, steam railroad, office buildings, hotels, schools and manufacturing	Anth.	0.223	0	0	12.0	3.6	4.5	3.9	*	12
	Coke	0.223	0	0	6.0	1.7	2.3	2.0	*	6
	Poc.	0.649	0	313.0	1,485.0	55.4	745.2	942.0	55.4	1,798
	Bit.	0.811	265.8	23,574.1	48,034.1	3,011.5	23,574.6	43,074.1	2,213.8	71,874
Totals	....	.....	265.8	23,887.1	49,537.1	3,072.2	24,326.6	44,022.0	2,269.2	73,690
Low Pressure Steam and Other Stationary Heating Plants: Buildings, apartments and residences	Anth.	0.138	0	0	2,444.0	17.8	779.2	1,647.0	*	2,444
	Coke	0.223	0	0	123.0	36.9	46.4	39.7	*	123
	Poc.	0.490	0	658.4	3,701.6	498.3	2,393.7	1,459.3	8.7	4,360
	Bit.	1.171	0	1,660.5	20,949.5	7,106.3	9,962.0	5,001.3	540.4	22,610
Totals	....	.....	0	2,318.9	27,218.1	7,659.3	13,181.3	8,147.3	549.1	29,537
Gas and Coke Plants (exclusive of boiler power plants)	Anth.	No tests made								
	Coke									
	Poc.									
	Bit.									
Furnaces for Metallurgical, Manufacturing and Other Processes (exclusive of boiler power plants): Steel plants, foundries, forges and allied processes	Anth.	1.798	0	107.0	468.0	8.7	125.4	433.6	7.3	575
	Coke	6.380	2,440.1	32,749.3	169,655.6	1,147.2	22,246.2	180,161.1	1,290.5	204,845
	Poc.	1.290	0	106.3	235.7	13.3	153.2	173.1	2.4	342
	Bit.	1.084	191.5	156.6	9,083.9	1,783.6	4,263.3	3,332.3	52.8	9,432
Totals	....	.....	2,631.6	33,119.2	179,443.2	2,952.8	26,788.1	184,100.1	1,353.0	215,194
Brick, pottery and allied processes	Coke	1.798	0	6.4	26.6	0.5	7.1	24.9	0.5	33
	Poc.	1.290	0	1.0	2.0	0.1	1.4	1.5	*	3
	Bit.	15.560	7.0	919.4	5,149.6	14.5	545.0	5,351.2	165.3	6,076
Totals	....	.....	7.0	926.8	5,178.2	15.1	553.5	5,377.6	165.8	6,112
Miscellaneous manufacturing, rendering and other processes	Anth.	0.223	0	0	28.0	8.4	10.6	9.0	*	28
	Coke	1.798	0	46.1	201.9	3.8	54.0	187.1	3.1	248
	Poc.	1.290	0	1.3	2.7	0.2	1.8	2.0	*	4
	Bit.	1.084	10.1	8.3	481.6	94.5	226.0	176.7	2.8	500
Totals	....	.....	10.1	55.7	714.2	106.9	292.4	374.8	5.9	780
Grand Totals	....	.....	9,020.4	78,030.6	270,947.0	14,002.6	83,271.2	255,594.7	5,129.5	357,998

* Less than 0.05 ton.

tions. A strong draft carries away any material which lies in its course and is sufficiently light to be borne on its current. The path of the solids is that which is followed by the currents of air and gases; these currents enter the furnace through the bed of fire and, passing along the flameway, enter by whatsoever channel may be provided into the smoke-stack, from which they pass on to the atmosphere. A weak draft, such as that which normally prevails in connection with domestic fires, implies fine dust particles and soot flakes only in the smoke, whereas a strong draft, such as that which commonly prevails in boiler plants served by lofty chimneys and in steam locomotives, implies the discharge of solid particles of considerable size.

Changes in the rate of combustion produce changes in the temperature of the fire, and changes in furnace temperatures effect changes in the character of the solids in smoke. Under normal conditions, low draft values imply low rates of combustion, low furnace temperatures and solids in smoke consisting largely of particles condensed from distillates driven out of the freshly applied fuels while in the process of being heated to the point of ignition. The solids include also very fine particles originating in the fuel, and its ash, which are sufficiently light to be borne away upon the current of the feeble draft. It is an interesting fact, as disclosed by the results of the Committee's investigations, that, while the individual particles discharged from fires of low temperature may be small, the percentage of the coal burned which is represented by the hydrocarbons and soot passing off with the smoke is relatively high. It is because of this high percentage of hydrocarbons that the solid constituents of smoke emitted from fires of low temperature constitute an important factor in the total pollution of the atmosphere of a city. While the emissions from an individual fire may be small, the number of such fires is large and the aggregate of solids discharged is correspondingly great.

High rates of combustion imply high furnace temperatures and smoke low in hydrocarbons and relatively free from soot. Solids from such fires include particles of partially consumed fuel which, in the processes of the furnace, are exposed to the action of a draft too strong to permit them to retain their place on the firebed. They include particles of fine ash which are readily caught up and carried away, also spherical slag particles picked up from the firebed in a liquid state and solidified as they pass on their course into the atmosphere. The solid constituents of Illinois coal, when this coal is consumed in fires of high temperature, yield a considerable percentage of these spherical slag particles, varying in size from those which are almost microscopic to others approaching one-eighth of an inch in diameter. All such particles have a honeycomb structure and, when crushed under foot or by traffic in the streets, yield a fine powder which is easily borne away upon the wind.

105.33 Fuel Value of the Solid Constituents Emitted in Smoke: The solid constituents in smoke include both combustible and non-combustible materials. Only those which are combustible have fuel value. The loss of combustible material due to smoke is very low. It has, however, a detrimental effect on the economy of the boiler through the deposition of insulating particles on the heat absorbing surfaces. The loss due to this has in many cases been considerable. The actual fuel loss occurring in the several fuel consuming services, as determined by the researches of the Committee for the year 1912, in no case equals 1.0 per cent of the total fuel value of the coal fired. A more detailed statement of the extent of such fuel losses is set forth by table XCVIII.

TABLE XCVIII. COAL EQUIVALENT OF THE SOLID CONSTITUENTS OF SMOKE
ZONE A

Service	Coal Equivalent — Tons				Per Cent of Fuel Fired
	Tar	Carbon	Sulphur	Total	
1	2	3	4	5	6
Steam locomotives. .	162.2	14,145.0	193.8	14,501	0.69
Steam vessels.	37.2	567.6	2.2	607	0.75
High pressure plants	3,394.9	21,851.6	627.5	25,874	0.35
Low pressure plants.	9,313.5	13,157.2	166.3	22,637	0.54
Gas and coke plants.	3,464.8	26,976.4	435.8	30,877	0.84
Totals.	16,372.6	76,697.8	1,425.6	94,496	0.54

105.34 Solids in Smoke are not Eliminated when the Smoke Discharge is made Invisible: An important fact clearly defined by the investigations of the Committee, the significance of which has not before been generally appreciated, concerns the omnipresence of solids in smoke discharges. As shown in the preceding sections, the quantity and character of the solids in smoke may vary greatly, but smoke arising from solid fuels is never free from such solids. Again, the amount of solids discharged has no direct relation to visibility. A stack may appear smokeless to the eye and yet be the source of a heavy discharge of fuel dust. The adoption of anthracite coal or of coke as a fuel will serve to make stack discharges invisible but will not eliminate the

TABLE XCIX. DENSITY AND SOLID CONSTITUENTS OF SMOKE, AS DETERMINED FROM TESTS OF TYPICAL STATIONARY PLANTS

Test No.	Service	Kind of Fuel	Smoke Density Per Cent	Solids in Per Cent of Fuel Fired
1	2	3	4	5
103	Low pressure	Anthracite	0.00	0.118
104	" "	"	0.00	0.157
110	" "	Pocahontas	0.00	2.630
112	" "	"	0.00	0.378
87	High pressure	Bituminous	0.30	0.518
99	Low pressure	Pocahontas	0.43	0.246
15	High pressure	Bituminous	0.58	0.400
2	" "	"	0.66	0.530
86	" "	"	0.67	0.297
115	" "	Pocahontas	0.76	0.587
4	" "	Bituminous	0.89	0.840
18	" "	"	0.94	0.363
88	" "	"	1.38	0.640
98	Low pressure	Pocahontas	1.72	0.400
116	High pressure	"	1.75	0.715
9	" "	Bituminous	3.15	0.444
12	" "	"	3.68	0.362
89	" "	"	4.29	0.568
8	" "	"	6.26	2.460
33	" "	"	6.77	0.808
6	" "	"	6.88	0.200
5	" "	"	9.62	0.150
7	" "	"	12.00	1.070
1	" "	"	13.85	1.490
10	" "	"	20.00	1.110
17	" "	"	20.00	0.753
3	" "	"	21.97	0.830
66	" "	"	28.31	1.390
65	" "	"	29.50	1.379

dust discharge. Certain facts showing the persistence of the solid constituents of smoke in stacks exhibiting many grades of visible smoke are set forth by table XCIX.

GASEOUS CONSTITUENTS OF SMOKE

105.35 The Origin of Gases in Smoke: The gaseous constituents of smoke normally include compounds of carbon and sulphur which originate in the combustion of fuel, the component gases of air and other normal gases the volume of which is small and, for present purposes, negligible. The air supplies the oxygen necessary to combustion, but, because of the imperfect mixing of gases, it is generally supplied in greater amounts than can be absorbed in the processes of the furnace. As a consequence some oxygen commonly appears in smoke. The air also supplies nitrogen, which has no part in the process of combustion. Included with the gases resulting from the combustion of fuel may be found, in the case of smoke of industries, a great array of gases such as may arise from the treatment of materials of many descriptions by the application of heat. It is the purpose of this chapter to set forth the results of an investigation which has been made for the purpose of determining the characteristics of the more important gases in smoke and the extent to which they are produced by the several services in which fuel is used.

105.36 Gases Included in the Discharge from Chimneys and Smoke-Stacks: The gaseous products of combustion which are to be regarded as most important in atmospheric pollution are:

Carbon dioxid (CO_2).
Carbon monoxid (CO).
Sulphur trioxid (SO_3).
Sulphur dioxid (SO_2).

Other important gases present in the discharges from chimneys and stacks are oxygen and nitrogen which, in combination, form air. Owing to the fact that part of the oxygen present in the air which passes into the furnace is combined with other elements in the formation of gaseous compounds, only a part of the air present in stack discharges has its normal content of oxygen. For this reason determination was made to disclose the volume of air and the volume of nitrogen present in the smoke discharges, in addition to the volume of each of the several gaseous compounds resulting from combustion.

The compounds of carbon and sulphur found in smoke have their origin in that portion of the carbon and sulphur in the fuel which is converted into gaseous form by the process of combustion. They comprise by weight an average of approximately 96 per cent of all the products of combustion which are constituents of smoke, and the carbon and sulphur content of the fuel from which they originate comprises from 50 to 90 per cent of the total weight of the fuel consumed.

Carbon dioxid, being heavier than air, possesses a tendency to settle near the surface of the earth. When combined with water it is corrosive. Its effect upon the atmosphere is chiefly that of a diluting agency.

Carbon monoxid is colorless and inodorous. It is slightly lighter than air and therefore possesses a tendency to rise from the surface of the earth. It is not present in sufficient quantities to constitute an objectionable source of atmospheric pollution.

Sulphur trioxid when introduced into the atmosphere is deliquescent and is violently suffocating. It is heavier than air and tends to settle near the earth. In the atmosphere, it readily changes to sulphuric acid when combined with moisture. As sulphuric acid, it is corrosive to iron and steel, and injurious to vegetation and building materials.

Sulphur dioxid has a pungent and stifling odor. It is heavier than air and tends to remain near the earth. After emission into the atmosphere, it gradually oxidizes to sulphur trioxid which, in contact with moisture, becomes sulphuric acid. The rate of change from sulphur dioxid to sulphuric acid depends upon atmospheric conditions, and the gas may be carried long distances from its point of emission before the change is completed.

It will be hereinafter shown (chapter 113), from analyses of samples of air taken at various points throughout the city of Chicago, that those gases which are important constituents of samples taken from smoke-stacks are readily diffused upon entering the atmosphere. Their volume is large but so, also, is the capacity of the atmosphere for absorbing them, and as polluting agencies their effects are relatively slight. The discussion which follows is justified chiefly on account of the popular interest in this subject.

Information concerning the gases contained in smoke has been derived from two series of investigations involving:

1. Analyses of samples of flue-gases taken from the smoke-stack of a locomotive on a testing plant, from smoke-stacks of steam vessels and from the stacks of stationary plants in various services throughout the Area of Investigation.
2. Analyses of representative samples of the fuels burned in various services.

By these processes, the volume of each gas and the relation between the gases and the fuel consumed were determined.

105.37 Determinations with Reference to the Gaseous Constituents of Steam Locomotive Smoke: Information relating to the gases emitted in locomotive smoke was obtained from analyses made of samples of smoke in connection with the laboratory tests of a locomotive at Altoona, Pa. (section 105.24).

The amounts of carbon dioxid and carbon monoxid in locomotive smoke were determined by testing samples of flue-gas taken continuously from the smoke-box of the locomotive by means of a special smoke sampling device. The samples were analyzed according to the volumetric method usually employed for flue-gas analysis.

Samples of gases used to determine the amounts of sulphur trioxid and sulphur dioxid contained in locomotive smoke were drawn from a point near the top of the smoke-stack. The apparatus employed for this purpose was similar to that illustrated by fig. 25. It consisted of an intake pipe covered with a screen which intercepted the cinders, a series of six bottles containing water and chemical solutions through which passed the gases to be analyzed, a gas meter, a thermometer, a manometer, and a steam aspirator which induced the flow of the gases through the apparatus. The sulphur trioxid, in the sample thus obtained, was changed to sulphuric acid upon coming in contact with water contained in the first bottle and was retained by the water. The sulphur dioxid content, which is not affected by water, passed with the remaining gases through three solutions of iodine and was thereby oxidized to sulphur trioxid, which in turn was changed to sulphuric acid and retained by the water in the iodine solutions. The fifth and sixth solutions were used for purposes incident to the operation of the apparatus. The volume of the gases was accurately determined by meter after passing through the solutions. Analyses of the contents of the several solutions in which the two sulphur gases were retained served to disclose the percentage by volume of sulphur trioxid and sulphur dioxid.

The relation between the sulphur and the carbon in the gaseous constituents of smoke was established as a result of analyses of samples obtained in each test.

A determination of the total weight of carbon contained in the coal used was based upon ultimate analyses of the coal. From the weight of carbon thus determined were deducted the weight of the carbon contained in the materials discharged through the grate and that of the carbon contained in the solid constituents of smoke discharged through the stack. The remainder represents the weight of the carbon contained in the flue-gases discharged through the stack.

Values for the carbon contained in the carbon dioxid and in the carbon monoxid were determined by applying the ratios of the two gases to each other, respectively, to the weight of the carbon contained in the flue-gases. The amount of sulphur contained in the combined sulphur gases was determined by multiplying the weight of the carbon in the flue-gases by the ratio of the sulphur in the sulphur gases to the carbon in the carbon gases. From this result values for the sulphur in the sulphur trioxid and in the sulphur dioxid were determined, the relation between the two sulphur gases being known. These values in all cases represented the weights of the components of the several gases which were contributed by the fuel.

The values thus obtained from the tests made on the locomotive testing plant were tabulated and plotted as diagrams showing the amount of each gas emitted during the burning of the different coals used, at the various rates of combustion employed. In plotting the lower portions of these curves it was assumed that, as the rate of combustion approaches zero, sufficient air enters the furnace to supply the necessary oxygen to support combustion and that all of the carbon in the fuel is emitted in smoke as carbon dioxid. It was assumed also that, as the rate of combustion approaches zero, the rates of emission of the sulphur gases do not change from the values obtained at the minimum rate of combustion (about 25 pounds per square foot of grate surface per hour) recorded by the tests on the locomotive testing plant. The maximum rate of combustion employed in the locomotive laboratory tests exceeded the average maximum of those in any class of locomotive service in the Area of Investigation. Values were taken from these curves for each of the carbon and sulphur gases corresponding to different rates of combustion, from 10 to 100 pounds of fuel per square foot of grate surface per hour, the increase proceeding by increments of 10, and these values were averaged. These averages provided a basis upon which other diagrams were plotted. One of these is presented as fig. 27.

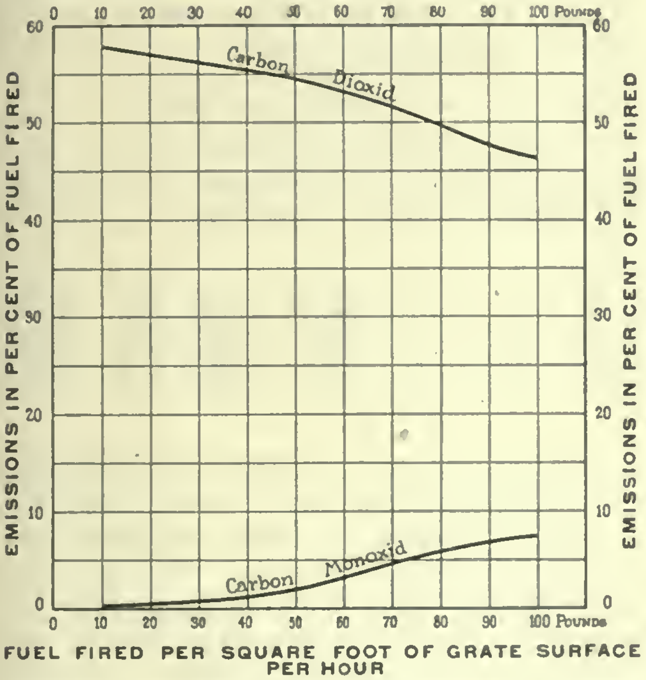

FIG. 27. CARBON DIAGRAM. Quantities of Carbon as Carbon Compounds Emitted in Smoke of Locomotives at Varying Rates of Combustion.

The rate of emission for each of the several gases corresponding to any desired rate of combustion may be read directly from the diagrams. In order, however, to apply these values in a determination of the extent to which each class of locomotive service contributes to the production of the gases in smoke, it was necessary to determine the average rate of combustion for each locomotive service. This was accomplished as a result of tests conducted on locomotives in service (section 105.25). The data which was obtained from these tests indicate that the average rate of combustion, while running, for each of the different classes of locomotive service is as follows:

Yard:
35.5 lb. per sq. ft. of grate surface per hour.
Road freight:
40.6 lb. per sq. ft. of grate surface per hour.
Freight transfer:
37.0 lb. per sq. ft. of grate surface per hour.
Passenger transfer:
28.0 lb. per sq. ft. of grate surface per hour.
Through passenger:
52.2 lb. per sq. ft. of grate surface per hour.
Suburban passenger:
62.7 lb. per sq. ft. of grate surface per hour.

It was assumed, in making determinations with reference to gases, that all the fuel was consumed at the rates of combustion which obtained while running.

By multiplying the rate of emission of each of the several gases, corresponding to the average rate of combustion for any of the locomotive services as presented, by the amount of fuel consumed in that service, a value was obtained which represented the amount of carbon or sulphur contributed by the fuel to the production of the gas in question.

From standard values relating to the volume of gases, the number of cubic feet of gas (at 62 degrees Fahrenheit and 30 inches mercury pressure) produced by the conversion of one pound of carbon into carbon dioxid was determined. This volumetric value, when multiplied by the total weight of the carbon contributed to the production of carbon dioxid by the fuel consumed in any service, serves to indicate the total volume of the carbon dioxid produced by the service in question. From the analyses of flue-gases, the relation between the carbon dioxid and each of the other gases under determination was known, and by the use of such ratios the volume of each of the other gases produced in the service in question was determined.

All the tests described were conducted with Illinois and Indiana bituminous coals. The results were considered sufficiently similar to be applicable, however, to the small amount of Pocahontas coal burned by locomotives in the Area of Investigation.

The values obtained from the gas analyses described, expressed in cubic feet per ton of fuel consumed, are presented as table C. The values for the nitrogen and air contained in the discharge from the smoke-stack are also given.

TABLE C. VOLUME OF GASES PER TON OF FUEL CONSUMED. ALL LOCOMOTIVE SERVICES

Service	Kind of Fuel	Cubic Feet (at 62° F. and 30 inches mercury pressure) of Gases Emitted per Ton of Fuel Consumed							
		Carbon Dioxid (CO_2)	Carbon Monoxid (CO)	Sulphur Trioxid (SO_3)	Sulphur Dioxid (SO_2)	Nitrogen (N)	Total Gases from Combustion	Air	Total Emissions
1	2	3	4	5	6	7	8	9	10
Steam Locomotives:									
Yard	Bit.	35,329	609	187	83	167,849	204,055	100,505	304,560
Road freight	Bit.	35,075	594	169	79	164,726	200,643	96,605	297,248
Freight transfer	Bit.	35,266	603	180	81	167,325	203,455	97,960	301,415
Passenger transfer	Bit.	35,773	308	211	90	168,695	205.077	103,310	308,387
Through passenger	Bit.	34,505	2,805	117	87	170,075	207,589	72,935	280,524
Suburban passenger	Bit.	33,743	1,673	134	75	160,975	196,600	82,270	278,870
Locomotive terminals	Bit.	*35,773	*308	*211	*90	*168,695	*205,077	*103,310	*308,387

* Taken from tests representing equivalent conditions.

105.38 Gaseous Constituents of Smoke from Steam Vessels and Stationary Plants: Data relating to the gases contained in smoke arising from furnaces of steam vessels and stationary plants in the Area of Investigation were obtained from analyses of samples of smoke procured as a result of the smoke sampling tests described in section 105.26, which embrace representative conditions in all classes of service other than locomotive service.

The amounts of carbon dioxid and carbon monoxid in smoke of steam vessels and stationary plants were determined by analyses of flue-gases drawn from the smoke-stack at frequent intervals during each smoke sampling test by means of a gas analyzing device which is shown as one of the units of the apparatus illustrated by fig. 25. A sample from the stream of gases passing through the smoke-stack may be intercepted whenever desired and quickly analyzed by means of this apparatus. The process is similar to that which was employed in the laboratory in analyzing locomotive smoke for carbon gases (section 105.37). The results indicate the percentage by volume of each of the carbon gases.

The sulphur trioxid and the sulphur dioxid contained in smoke from steam vessels and stationary plants were determined by analyses of samples of flue-gases drawn continuously from the smoke-stack during each smoke sampling test by means of the apparatus illustrated in fig. 25, the flow through which is induced by a pump. By the process employed, the sulphur compounds are converted into sulphuric acid upon coming in contact with the water and with chemical solutions through which the intercepted stream is drawn, and in this form are absorbed and retained, the method being similar to that employed in analyzing locomotive smoke for sulphur compounds (section 105.37). The values obtained represent the percentage by volume of sulphur trioxid and sulphur dioxid.

The volume of the stream of gases intercepted by the smoke sampling apparatus was measured by meter after passing through the solutions employed in the sulphur gas determinations, and the relation between this volume and that of the total discharge through the smoke-stack was established by a knowledge of the relative area of the intake pipe of the apparatus and that of the smoke-stack, the velocity of flow through the apparatus being maintained to correspond to that of the flow through the smoke-stack by means of a regulating device.

As a result of the volumetric tests described, the percentage of the total volume of gases discharged represented by each of the gases under determination was ascertained. From the record of the amount of fuel consumed during each test, a relation was established between the fuel consumed and the volume of gases discharged. Correction was made for temperature and pressure so that the results represent values at 62 degrees Fahrenheit and 30 inches mercury pressure. Averages of the results of all tests with similar fuels in each service provided a factor which could be applied to the total amount of such fuel consumed in the service in question to determine the total volume of the several gases produced.

The tests described included all important combinations of fuels and classes of service, but did not embrace a few cases in which comparatively small amounts of certain fuels were burned in certain services. For such instances values were accepted from the results of tests conducted under conditions which were equivalent or similar. The instances in question were as follows:

The results of tests with anthracite coal burned under strong drafts in an industrial furnace were considered applicable to the small amount of anthracite coal burned by steam vessels and by high pressure steam stationary power and heating plants, and also to the small amount of coke burned in high pressure steam stationary power and heating plants and in low pressure steam and other stationary heating plants.

The results of tests with Pocahontas coal burned by steam vessels were considered applicable to Pocahontas coal burned in furnaces for manufacturing, metallurgical and other processes.

The results of tests in passenger transfer service were considered applicable to locomotives at locomotive terminals. Other adaptions of results are indicated in table CI.

By the processes described the volume of each of the carbon and sulphur gases, of the air and of the nitrogen contained in the smoke emitted by each class of service, expressed in cubic feet per ton of fuel, was determined. These results, together with which are included results of the locomotive tests (table C) are presented as table CI.

105.39 Relative Standing of Different Services as Producers of Gases in Smoke: The product of the volumetric values per ton of fuel, as set forth by tables C and CI, and the quantity of fuel consumed annually in any service serves to disclose the total volume of gases produced annually by the service in question. The relation between the total volume of gases emitted in the smoke of the several services and the total volume of gases from all services represents the relative standing of the different services as producers of gases in smoke. Values determined in this manner for each service, indicating the total volume emitted during 1912 of each of the gases under consideration and the relative standing of the several services, are presented as tables CII, CIII and CIV.

The relative standing of the several services as producers of gases in smoke is shown graphically by fig. 28.

TABLE CI. VOLUME OF GASES PER TON OF FUEL CONSUMED. ALL SERVICES

Service	Kind of Fuel	Cubic Feet (at 62° F. and 30 inches mercury pressure) of Gases Emitted per Ton of Fuel Consumed							
		Carbon Dioxid (CO_2)	Carbon Monoxid (CO)	Sulphur Trioxid (SO_3)	Sulphur Dioxid (SO_2)	Nitrogen (N)	Total Gases from Combustion	Air	Total Emissions
1	2	3	4	5	6	7	8	9	10
Steam Locomotives:									
Yard	Bit.	35,329	609	185	83	167,849	204,055	100,505	304,560
Road freight	Bit.	35,075	594	169	79	164,726	200,643	96,605	297,248
Freight transfer	Bit.	35,266	603	180	81	167,325	203,455	97,960	301,415
Passenger transfer	Bit.	35,773	308	211	90	168,695	205,077	103,310	308,387
Through passenger	Bit.	34,505	2,805	117	87	170,075	207,589	72,935	280,524
Suburban passenger	Bit.	33,743	1,673	134	75	160,975	196,600	82,270	278,870
Locomotive terminals	Bit.	*35,773	* 308	*211	* 90	*168,695	*205,077	*103,310	*308,387
Steam Vessels:									
Tugs and lighters	Anth.	*28,843	*20,430	* 7	* 84	*190,991	*240,355	*2,163,220	*2,403,575
River barges, dredges, etc	Poc.	27,251	26,090	72	46	282,896	336,355	19,225	355,580
Lake steamers and barges	Bit.	36,151	14,190	73	95	251,878	302,387	35,475	337,862
High Pressure Steam Stationary Power and Heating Plants: Public service, municipal, steam railroad, office buildings, hotels, schools and manufacturing	Anth.	*28,843	*20,430	* 7	* 84	*190,991	*240,355	*2,163,220	*2,403,575
	Coke	*28,843	*20,430	* 7	* 84	*190,991	*240,355	*2,163,220	*2,403,575
	Poc.	50,053	0	9	139	207,879	258,080	1,029,520	1,287,600
	Bit.	38,446	2,768	8	214	213,244	254,680	1,047,410	1,302,090
Low Pressure Steam and Other Stationary Heating Plants: Buildings, apartments and residences	Anth.	36,133	6,838	19	53	186,625	229,668	1,360,140	1,589,808
	Coke	*28,843	*20,430	* 7	* 84	*190,991	*240,355	*2,163,220	*2,403,575
	Poc.	31,508	2,167	30	53	166,505	200,263	1,111,030	1,311,293
	Bit.	37,906	5,890	49	189	199,690	243,724	593,320	837,044
Gas and Coke Plants: Public service Other service	Anth. Coke Poc. Bit.	No Tests Made							
Furnaces for Metallurgical, Manufacturing and Other Processes: Steel plants, laundries, forges and allied processes	Anth.	55,123	0	6	6	248,041	303,176	1,074,890	1,378,066
	Coke	51,355	3,275	18	26	180,487	235,161	197,985	433,146
	Poc.	*27,251	*26,090	* 72	* 46	*282,896	*336,355	* 19,225	* 355,580
	Bit.	39,055	318	46	96	197,036	236,551	239,420	475,971
Brick, pottery and allied processes	Coke	*55,123	* 0	* 6	* 6	*248,041	*303,176	*1,074,890	*1,378,066
	Poc.	*27,251	*26,090	* 72	* 46	*282,896	*336,355	* 19,225	* 355,580
	Bit.	48,607	2,650	41	512	189,404	241,214	723,400	964,614
Miscellaneous manufacturing, rendering and other processes	Anth.	28,843	20,430	7	84	190,991	240,355	2,163,220	2,403,575
	Coke	*55,123	* 0	* 6	* 6	*248,041	*303,176	*1,074,890	*1,378,066
	Poc.	*27,251	*26,090	* 72	* 46	*282,896	*336,355	* 19,225	* 355,580
	Bit.	*39,055	* 318	* 46	* 96	*197,036	*236,551	* 239,420	* 475,971

* Values adapted from determinations made under similar conditions.

TABLE CII. TOTAL VOLUME OF GASES EMITTED IN THE SMOKE OF DIFFERENT SERVICES DURING 1912

ZONE A

Service	Fuel Consumed		Cubic Feet (at 62° F. and 30 inches mercury pressure)						Rating-Gases of Combustion Per Cent	Cubic Feet (at 62° F. and 30 inches mercury pressure)	
	Kind	Tons	Carbon Dioxid (CO_2)	Carbon Monoxid (CO)	Sulphur Trioxid (SO_3)	Sulphur Dioxid (SO_2)	Nitrogen (N)	Total Gases from Combustion		Air	Total Emissions
1	2	3	4	5	6	7	8	9	10	11	12
Steam Locomotives:											
Yard	Bit.	1,049,516	37,078,350,764	639,155,244	194,160,460	87,109,828	176,160,211,084	214,158,987,380	5.17	105.481.605.580	319.640,592.960
Road freight	Bit.	136,115	4,771,233,625	80.852.310	23,003,435	10,753,085	22.421,670.490	27.310.521,945	0,66	13.149.389.575	40,459,911,520
Freight transfer	Bit.	354,802	12,512,447,332	213.945.606	63.864,360	28,738,962	59.367,214,650	72.186.240.910	1,74	34,756,403.920	106.942,644,830
Passenger transfer	Bit.	21,370	764.469,010	6.581,960	4.509.070	1.923.300	3,605,012.150	4,382,495,490	0,10	2,207,734,700	6,590.230,190
Through passenger	Bit.	176,761	6,099,138,305	495,814,605	20,681.037	15.378.207	30,062,627,075	36.693,639,229	0,89	12,892,063,535	49.585.702.764
Suburban passenger	Bit.	155,327	5,241,198,961	259.862,071	20.813,818	11.649.525	25,003.763.825	30,537,288,200	0,74	12.778.752,290	43,316.040,490
Locomotive terminals	Bit.	205,153	7.338.938,269	63,187,124	43.287,283	18.463,770	34,608.285.335	42,072,161.781	1.01	21.194.356,430	63.266.518.211
Totals	......	....	73.808.776,266	1,759,398,920	370,319,463	174,016,677	351.228,823,609	427.341,334,935	10.31	202.460.306.030	629,801,640.965
Steam Vessels:											
Tugs and lighters	Anth.	112	3,230.416	2.288,160	781	9.408	21,390,992	26,019,760	*	242,280.640	269,200.400
	Poc.	3.748	102,136.748	97.785,320	269,856	172.408	1,060,294.208	1.260,658,540	0.03	72,055,300	1,332,713.840
	Bit.	31,293	1,131.273.243	444.047.670	2,284,389	2.972,835	7,882,018,254	9,462.596.391	0 23	1.110.119,175	10,572,715,566
River barges, dredges, etc.	Poc.	1,186	32,319,686	30,912,740	85,392	54.556	335,514,656	398,917,030	0.01	22,800,850	421,717,880
	Bit.	0,339	337,614,189	132.520.410	681,747	887.205	2,352,288,612	2,823,992,193	0.07	331,301,025	3.155,293.218
Lake steamers and barges	Bit.	35,697	1.290.482,247	506,540.130	2.605,881	3,391,215	8,991,288,966	10,794,308,739	0 26	1.260,351,075	12.060.659,814
Totals	......	....	2,897,056,529	1,214,124,730	5.028.649	7.487.627	20,642.795,718	24.767,392,653	0.60	3,014.908,065	27.812.300.718
High Pressure Steam Stationary Power and Heating Plants; Public service, municipal, steam railroad, office buildings, hotels, schools and manufacturing	Anth.	5.291	152.608,313	108,095.130	37,037	441.444	1,010,533,381	1.271,718,305	0,03	11.145.597,020	12,717,315,325
	Coke	2.121	61.176,003	43.332,030	14,847	178.164	405,091,911	509,792.955	0.01	4.588.189.620	5,097,982,575
	Poc.	262.196	13.123,696,388	0	2,359.764	36,415,244	54,505,042.284	67,667,543,680	1.63	269,936,025,920	337,603,569,600
	Bit.	7,046.649	270,915.467,454	19,505,124.432	56.373.192	1.507,082.886	1,502,655,619.356	1,794,640,567.320	43.29	7,380,730,629,090	9.175.371,196.410
Totals	......	....	284.252.948.158	19,656.551.592	58,784.840	1,545,050.738	1,558,576,286,932	1,864,089,622.260	44.96	7,666,700,441,650	9,530.790,063,910
Low Pressure Steam and Other Stationary Heating Plants: Buildings, apartments and residences	Anth.	1.577,761	57,009,238.213	10.788.729.718	29,077,450	83.621.333	294,419,646,625	362,361,213,348	8.74	2,145,975,846,540	2.508.337.059.888
	Coke	41,181	1,187,783.583	841.327.830	288.267	3,459.204	7.865.200.371	9,898,059,255	0.24	89,083,562,820	98.081,622.075
	Poc.	849.185	26,756,120.980	1.840,183.895	25,475,550	45,006.805	141,393,548,425	170,060,335,655	4,11	943,470.010,550	1.113.530,346.208
	Bit.	1,686,619	63.932,079,814	0,934.185,910	82.641.331	318.770.991	336,800,948,110	411.069,529.156	9.91	1,000,704.785,080	1.411.774,314,236
Totals	......	......	148,886,122.590	23.404,427.353	138,385,607	450,858.333	780.509,343,531	053,389,137.114	23.00	4,179,234,204.090	5,132,623,342,407
Gas and Coke Plants (exclusive of boiler power plants):											
Public service	Anth.	5.882	No Tests Made								
	Coke	133,643									
Other services	Anth.	245									
	Poc.	2,366									
	Bit.	92,415									
Furnaces for Metallurgical, Manufacturing and Other Processes (exclusive of boiler power plants): Steel plants, foundries, forges and allied processes	Anth.	31.442	1,733.177,366	0	188.652	188,652	7.798.905.122	9,532,459.792	0.23	33,796.691,380	43,329,151,172
	Coke	2.909,360	149.410.182,800	9.528.154.000	52,368.480	75,613.360	525.101.658.320	684,168,006,960	16.50	576,009,639.600	1,260,177,646,560
	Poc.	26,368	718,554.368	687,941.120	1,808.496	1,212.928	7.459.401.728	8.869.008,640	0.21	506,924,800	9.375.933,440
	Bit.	651,187	25,432.108.285	207,077.466	29.954.602	62.513.952	128.307,281,732	154.038.936,037	3.72	155.907.191,540	309,946,127,577
Totals	......	....	177,294,022,819	10.423,172,586	84,410,230	139.558.892	668.667,246,902	856,608.411.429	20.66	766,220,447.320	1.622,828.858.749
Brick, pottery and allied processes	Coke	206	11.355,338	0	1.236	1,236	51,096.416	62.454.256	*	221,427,340	283,881,596
	Poc.	0	0	0	0	0	0	0	0	0	0
	Bit.	8.165	396,876.155	21,637,250	334,765	4.180.480	1.546.483,660	1.969.512.310	0.05	5,906,561,000	7.876.073.310
Totals	......	....	408,231,493	21.637,250	336,001	4.181.716	1.597.580,106	2.031.966.566	0.05	6.127.988,340	8,159,954.906
Miscellaneous manufacturing, rendering and other processes	Anth.	12,269	353,874,767	250.655,670	85.883	1.030.596	2.343.268.579	2.948,915,495	0.07	26.540,546,180	29,489,461,675
	Coke	12.791	705.078,293	0	76,746	76.716	3,172.692.431	3.877,924,216	0.09	13,748,917.990	17,626,842,206
	Poc.	322	8,774,822	8.400.980	23.184	11.812	01.092,512	108.306,310	*	6.190,450	114,496,760
	Bit.	44,440	1,735,604,200	14,131.920	2.044,240	4,266.240	8.756.279,840	10.512,326,440	0.26	10.639,824,800	21,152,151,240
Totals	......	....	2,803.332,082	273.188.570	2.230,058	5,388.394	14.363.333,362	17.417,472.461	0.42	50,935.479,420	68,382,951,881
Grand Totals	......	....	690.350.489.937	56,752.501.001	660.394,243	2,326.512.377	3.395.585,410,160	4,145,675.337.718	100.00	12.874,723,775.815	17.020.399.113,536

* Less than 0.005 per cent.

TABLE CIII. TOTAL VOLUME OF GASES EMITTED IN THE SMOKE OF DIFFERENT SERVICES DURING 1912
ZONE B

Service	Fuel Consumed		Cubic Feet (at 62° F. and 30 inches mercury pressure)						Rating-Gases of Combustion Per Cent	Cubic Feet (at 62° F. and 30 inches mercury pressure)	
	Kind	Tons	Carbon Dioxid (CO_2)	Carbon Monoxid (CO)	Sulphur Trioxid (SO_3)	Sulphur Dioxid (SO_2)	Nitrogen (N)	Total Gases from Combustion		Air	Total Emissions
1	2	3	4	5	6	7	8	9	10	11	12
Steam Locomotives:											
Yard	Bit.	313.987	11.092,846.723	191,218,083	58,087.595	26.060,921	52.702,403.963	61.070,617.285	7.43	31.557.263.435	95,627.880.720
Road freight	Bit.	122.672	4,302.720.400	72,867,168	20.731.568	9.691.088	20.207.267.872	24.613.278.096	2.85	11.850.728,560	36,464,006.656
Freight transfer	Bit.	124,936	4,405.992,976	75,336,408	22,488,480	10.119,816	20.904,916.200	25.418.853.880	2.95	12.238,730,560	37.657,584.440
Passenger transfer	Bit.	175	6.260.275	53.900	36,925	15,750	29,521.625	35,888.475	*	18,079.250	53,967 725
Through passenger	Bit.	63,527	2.191.999,135	178,193,235	7.432.659	5,526,849	10,804,354,525	13.187.506.403	1.53	4.633,341,745	17.820.848,148
Suburban passenger	Bit.	36.045	1.216.266.435	60,303,285	4,830,030	2.703,375	5,802.343,875	7.086,447.000	0.82	2.965,422.150	10,051.869.150
Locomotive terminals	Bit.	55,014	1.968,015.822	16,944,312	11.607.954	4,951,260	9,280.586.730	11.282,106.078	1.31	5.683.496.340	16.965,602.418
Totals	...	....	25.184.101.766	594,916.391	125,215.211	59.069.059	119,731.394.790	145.694.697.217	16.89	68,947,062.040	214.641.759.257
Steam Vessels:											
Tugs and lighters	Anth.	12	346.116	245.160	84	1.008	2,291.892	2.884.260	*	25,958.640	28,812.900
	Poc.	234	6.376,734	6,105.060	16,848	10.764	66,197.664	78.707.070	0.01	4,498.650	83,205.720
	Bit.	8,579	310.139.429	121,736.010	626,267	815.005	2.160,861,362	2,594.178.073	0.31	304,340,025	2,898,518.098
River barges, dredges, etc.	Poc.	82	2.234,582	2.139.380	5,904	3,772	23,197,472	27.581.110	*	1,576.450	29.157,560
	Bit.	1,132	40,922.932	16,063,080	82,636	107,540	285.125,896	342,302,084	0.04	40.157,700	382.459,784
Lake steamers and barges	Bit.	954	34.488.054	13.537,260	69,642	90,630	240.291,612	288.477.198	0.03	33,843.150	322,320.348
Totals	.....	.....	394.507.847	159.825.950	801,381	1.028.719	2,777.965.898	3.334.129.795	0.39	410.374.615	3,744.504.410
High Pressure Steam Stationary Power and Heating Plants: Public service, municipal, steam railroad, office buildings, hotels, schools and manufacturing	Anth.	0	0	0	0	0	0	0	0	0	0
	Coke	423	12.200,589	8.641,890	2.961	35,532	80.789,193	101.670.165	0.01	915.042.060	1.016,712.225
	Poc.	14.824	741.985,672	0	133,416	2.060.536	3.081.598.296	3.825.777.920	0.44	15,261,604.480	19.087,382.400
	Bit.	1.815.830	69,811,400.180	5.026,217,440	14,526,640	388.587.620	387.214.852.520	462.455.584.400	53.63	1,901.918.500.300	2,364,374,084.700
Totals	......	......	70.565.586,441	5.034.859.330	14.663,017	390.683.688	390.377.240.009	466.383.032.485	54.08	1,918,095.146,840	2,384.478,179,325
Low Pressure Steam and Other Stationary Heating Plants: Buildings, apartments and residences	Anth.	193,511	6.992.132.963	1.323,228.218	3.676,709	10.256.083	36.113.990.375	44,443.284.348	5.15	263.202,051,540	307,645,335,888
	Coke	13.896	400.802.328	283.895.280	97.272	1,167.264	2,654.010.936	3.339,973,080	0.39	30,060,105,120	33,400,078,200
	Poc.	40.543	1.277.428.844	87,856.681	1.216,290	2.148,779	6,750,612.215	8,119,262,809	0.94	45,044,489.290	53,163.752,099
	Bit.	244.214	9.257,175.884	1.438,420,460	11.966.486	46.156,446	48,767,093,660	59,520.812.936	6.90	144,897,050,480	204.417,863,416
Totals	......	......	17.927.540,019	3.133.400,639	16.956,757	59.728.572	94,285,707,186	115.423,333.173	13.38	483,203,606,430	598,627,029,603
Gas and Coke Plants (exclusive of boiler power plants):											
Public service	Anth.	0	No Tests Made								
	Coke	18.159									
Other services	Anth.	0									
	Poc.	0									
	Bit.	1,157									
Furnaces for Metallurgical, Manufacturing and Other Processes (exclusive of boiler power plants): Steel plants, foundries, forges and allied processes	Anth.	529	29.160.067	0	3.174	3,174	131,213,689	160,380.101	0.02	568,616,810	728,996,914
	Coke	301.373	15,477.010.415	986.996,575	5,424,714	7,835,698	54.393,908,651	70,871.176,053	8.22	59.667,333,405	130,538,509.458
	Poc.	162	4,414,662	4.226,580	11,661	7.452	45,829,651	54,489,510	0.01	3,114,450	57,603,960
	Bit.	218.905	8.549.334.775	69.611,790	10,069.630	21.014,880	43.132,165.580	51.782,196,655	6.00	52,410,235,100	104,192,431,755
Totals	......	....	24,059.919.919	1,060.834,945	15,509.182	28.861,204	97.703,117,072	122,868.242.322	14.25	112.649,299.765	235,517,542,087
Brick, pottery and allied processes	Coke	1,633	90.015.859	0	9.798	9,798	405.050.953	495.086.408	0.06	1,755,295,370	2,250,381,778
	Poc.	200	5.450.200	5.218,000	14,400	9,200	56.579.200	67,271.000	0.01	3,845,000	71,116,000
	Bit.	30.888	1.501.373,016	81,853.200	1.266,408	15,814,656	5.850.310.752	7.450,618.032	0.86	22,344,379,200	29,794,997,232
Totals	......	......	1,596.839,075	87.071,200	1,290,606	15.833,654	6,311.940.905	8.012.975,440	0.93	24,103.519.570	32,116,495,010
Miscellaneous manufacturing, rendering and other processes	Anth.	104	2.999.672	2.124.720	728	8.736	19.863.064	24.996.920	*	224,974,880	249,971,800
	Coke	967	53.303,941	0	5.802	5.802	239.855.647	293.171.192	0.03	1,039,418,630	1,332,589,822
	Poc.	0	0	0	0	0	0	0	0	0	0
	Bit.	1,696	66,237.280	539,328	78,016	162.816	334.173.056	401.190,496	0.05	406,056,320	807,246,816
Totals	.....	.....	122.540,893	2.664,048	84,546	177 354	593.891.767	719.358,608	0.08	1,670,449,830	2,389,808,438
Grand Totals	......	.....	139.851.035.960	10.073,572.503	174.520,700	555,382,250	711.781.257.627	862,435.769,040	100.00	2,609,079.549,090	3,471,515,318,130

* Less than 0.005 per cent.

TABLE CIV. TOTAL VOLUME OF GASES EMITTED IN THE SMOKE OF DIFFERENT SERVICES DURING 1912
ZONES A AND B

Service	Fuel Consumed		Cubic Feet (at 62° F. and 30 inches mercury pressure)						Rating-Gases of Combustion Per Cent	Cubic Feet (at 62° F. and 30 inches mercury pressure)	
	Kind	Tons	Carbon Dioxid (CO_2)	Carbon Monoxid (CO)	Sulphur Trioxid (SO_3)	Sulphur Dioxid (SO_2)	Nitrogen (N)	Total Gases from Combustion		Air	Total Emissions
1	2	3	4	5	6	7	8	9	10	11	12
Steam Locomotives:											
Yard	Bit.	1.363.503	48.171.197.487	830.373.327	252,248.055	113.170.749	228.862.615.047	278,229.604,665	5.55	137,038.869,015	415,268.473,680
Road freight	Bit.	258.787	9,076,954.025	153.719.478	43,735,003	20.444.173	42,628.947.362	51,923.800,041	1.04	25,000,118.135	76,923,918.176
Freight transfer	Bit.	479,738	16,918,440,308	289,282,014	86.352.840	38.858.778	80.272.160.850	97,605,094,790	1.95	46,995,134.480	144,600.229.270
Passenger transfer	Bit.	21,545	770,729,285	6.635,860	4,545,995	1.939.050	3.634.533,775	4.418.383,965	0.09	2,225.813,950	6,644,197,915
Through passenger	Bit.	240,288	8,291.137,440	674.007.840	28.113.696	20.905.056	40,866,981,600	49,881,145,632	1.00	17.525.405.280	67.406.550,912
Suburban passenger	Bit.	191.372	6.457.465,396	320.165.356	25,643,848	14.352.900	30.806.107.700	37.623.735.200	0.75	15.744.174.440	53.367.909,640
Locomotive terminals	Bit.	260.167	9.306,954,091	80.131.436	54.895,237	23.415.030	43,888.872.065	53.354,267.859	1.06	26.877.852.770	80.232.120,629
Totals	...	....	98,992,878,032	2.354.315.311	495,534.674	233,085,736	470,960.218.399	573,036,032.152	11.44	271,407.368,070	844.443.400.222
Steam Vessels:											
Tugs and lighters	Anth.	124	3.576.532	2.533.320	868	10,416	23.682.884	29,804,020	*	268.239.280	298,043.300
	Poc.	3,982	108,513.482	103,890,380	286.704	183.172	1.126.491.872	1.339.365,610	0.03	76,553,950	1.415.919.560
	Bit.	39.872	1,411,412.762	565.783.680	2.910.656	3.787.840	10.042.879.616	12,056.774.464	0.24	1.414.459,200	13.471.233.664
River barges, dredges. etc.	Poc.	1.268	34.554.268	33,082.120	91.296	58.328	358.712.128	426.498.140	0.01	24.377.300	450,875,440
	Bit.	10,471	378,537.121	148,583.490	764.383	994.745	2.637,414.538	3.166,294,277	0.06	371,458,725	3.537,753.002
Lake steamers and barges	Bit.	36.651	1,324,970.301	520.077.690	2.675,523	3.481.845	9.231.580.578	11.082.785.937	0.22	1.300,194,225	12,382,980.162
Totals	......	......	3,291.564.376	1.373,950.680	6.729.430	8.516.346	23,420.761,616	28.101,522.448	0.56	3.455.282,680	31.556,805.128
High Pressure Steam Stationary Power and Heating Plants: Public service. municipal, steam railroad. office buildings. hotels. schools and manufacturing	Anth.	5.291	152.608,313	108.095.130	37.037	444.444	1,010.533.381	1.271.718.305	0.03	11.445.597.020	12.717.315.325
	Coke	2,544	73.376.592	51,973.920	17.808	213.696	485.881.104	611,463,120	0.01	5.503.231,680	6,114,694,800
	Poc.	277.020	13.865.682.060	0	2.493.180	38.505.780	57,586,640.580	71,493.321,600	1.43	285,197.630,400	356,690.952,000
	Bit.	8.862.479	340.726.867.634	24,531.341,872	70.899,832	1,896,570,506	1.889.870.471.876	2.257.096.151.720	45.07	9.282.649.129.390	11,539.745,281.110
Totals	....	....	354,818.534.599	24,691.410.922	73.447.857	1,935,734,426	1.948.953.526.941	2.330.472,654.745	46.54	9.584.795.588.490	11.915,268.243.235
Low Pressure Steam and Other Stationary Heating Plants: Buildings, apartments and residences	Anth.	1.771.272	64.001.371.176	12.111.957.936	33,654.168	93,877.416	330.563.637,000	406.804,497.696	8.12	2.409.177.898.080	2,815,982.395.776
	Coke	55,077	1.588.585.911	1.125,223.110	385.539	4,626.468	10,519.211,307	13,238.032,335	0.26	119.143.667.940	132.381,700.275
	Poc.	889.728	28,033.549.824	1.928.040,576	26,691.840	47.155.584	148.144,160.640	178,179.598,464	3.56	988,514.499.840	1,166.694,098,304
	Bit.	1,930,833	73.190.155.698	11.372,606.370	94.610.817	364.927.437	385,568,041.770	470,590.342,092	9.40	1.145.601.835.560	1,616.192,177.652
Totals	....	....	166.813,662,609	26.537,827.992	155,342,364	510,586,905	874.795.050.717	1,068.812.470.587	21.34	4.662.437.901.420	5,731.250,372,007
Gas and Coke Plants (exclusive of boiler power plants):											
Public service	Anth.	5.882	No Tests Made								
	Coke	151.802									
Other services	Anth.	245									
	Poc.	2.366									
	Bit.	93.572									
Furnaces for Metallurgical. Manufacturing and Other Processes (exclusive of boiler power plants): Steel plants, foundries. forges and allied processes	Anth.	31.971	1.762,337.433	0	191,826	191,826	7,930.118.811	9.692.839,896	0.19	34,365.308.190	44,058.148.086
	Coke	3.210,733	164,887,193.215	10,515.150.575	57.793.194	83.479.058	579,495.566.971	755.039.183,013	15.08	635,676.973,005	1.390.716.156.018
	Poc.	26,530	722,969.030	692.167.700	1.910.160	1,220.380	7.505,230.880	8,923.498.150	0.18	510,039.250	9.433.537.400
	Bit.	870,092	33.981.443.060	276,689,256	40.024,232	83.528,832	171,439.447.312	205,821.132,692	4.11	208.317.426,640	414.138,559.332
Totals	....	....	201.353,942.738	11.484.007,531	99.919,412	168.420,096	766.370.363.974	979.476.653.751	19.56	878.869.747.085	1,858.346.400.836
Brick. pottery and allied processes	Cok	1.839	101.371.197	0	11.034	11.034	456,147.399	557.540,664	0.01	1.976.722.710	2.534.263,374
	Poc.	200	5,450,200	5,218.000	14.400	9.200	56,579.200	67,271.000	*	3,845,000	71.116,000
	Bit.	39.053	1.898,249.171	103,190,450	1,601,173	19.995.136	7,396.794,412	9.420.130.342	0.19	28,250.940.200	37.671,070,542
Totals	....	......	2.005.070.568	108.708,450	1.626.607	20,015.370	7.909.521.011	10,044.942,006	0.20	30,231.507,910	40.276,449,916
Miscellaneous manufacturing, rendering and other processes	Anth.	12.373	356.874,439	252,780,390	86,611	1,039,332	2.363,131.643	2,973,912,415	0.06	26.765.521,060	29.739.433.475
	Coke	13.758	758.382,234	0	82.548	82,548	3,412.518,078	4.171,095.408	0.08	14.788.336.620	18.959,432,028
	Poc.	322	8.774,822	8.400,980	23.184	14.812	91,092.512	108,306.310		6,190.450	114.496.760
	Bit.	46.136	1.801.841.480	14.671,248	2.122.256	4.429.056	9,090,452.896	10,913.516.936	0.22	11.015,981.120	21.959.398,056
Totals	....	......	2.925.872,975	275.852.618	2.314.599	5.565.748	14.957,225,129	18.166.831.069	0.36	52,605.929.250	70.772.760.319
Grand Totals	....	......	830.201.525.897	66,826,073.504	834.914.943	2,881,924.627	4,107,366,667,787	5,008.111.106.758	100.0	15.483,803.324.905	20,491.914.431.663

* Less than 0.005 per cent.

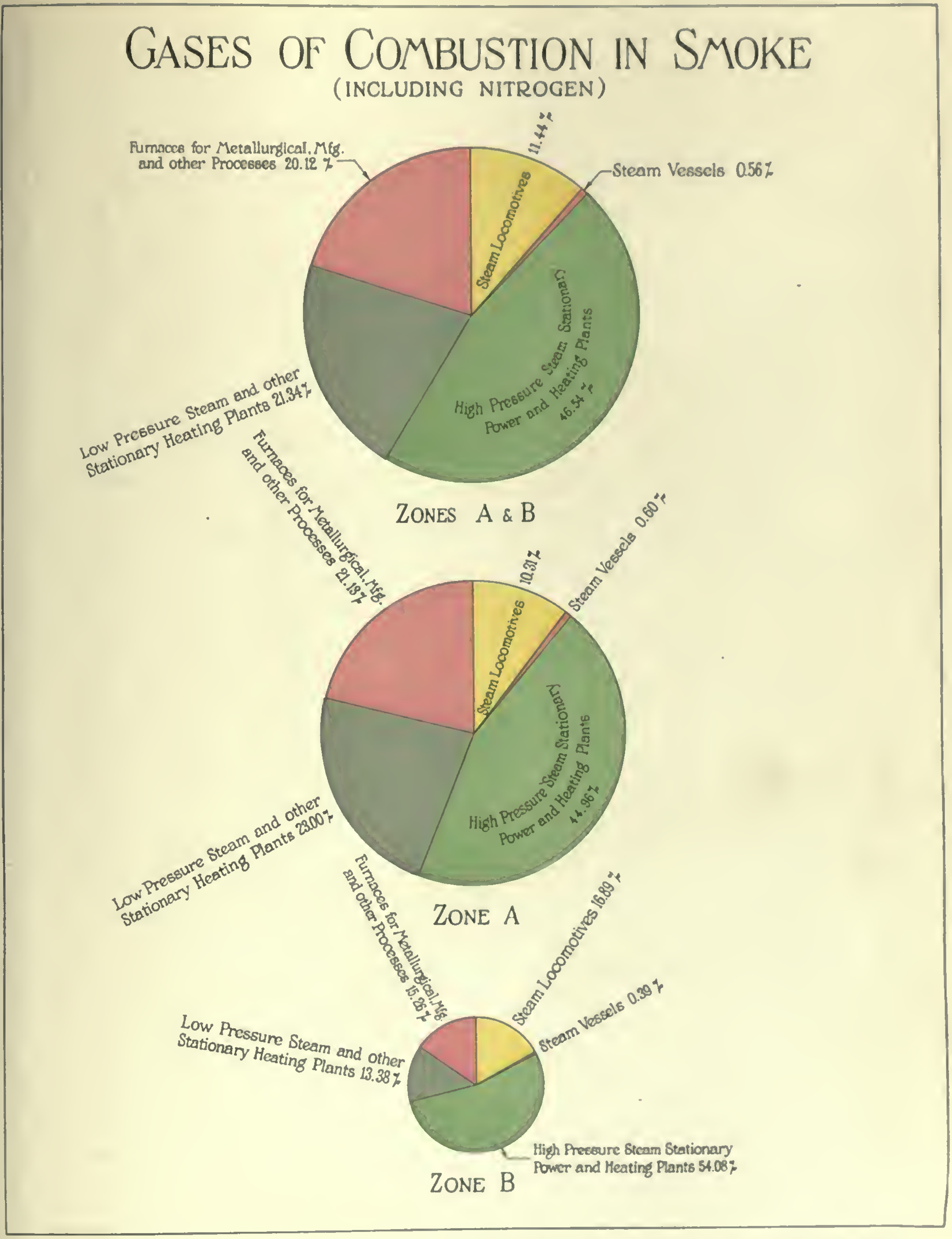

FIG. 28. RELATIVE STANDING OF THE SEVERAL SERVICES AS PRODUCERS OF GASES IN SMOKE

105.40 Summary of Flue-Gas Analyses: The ratio of the volume of each gas to the total volume of the gaseous discharges from the stack for each class of service, as disclosed by the tests previously described, is presented as table CV.

INCIDENTAL FACTS CONCERNING GASEOUS PRODUCTS OF COMBUSTION

105.41 Character of Fuel and Gaseous Constituents of Smoke: Solid fuels vary greatly in the amount of sulphur they contain. The quantity of sulphur compounds present in smoke discharges is a function of the amount of sulphur contained in the fuel. In the operation of furnaces, sulphur in the fuel may be disposed of in three ways, namely:

1. By being precipitated through the grate into the ash-pit.
2. By being discharged into the atmosphere through the stack as a solid constituent of smoke.
3. By being discharged into the atmosphere through the stack as a gaseous compound.

Illinois coal, having a comparatively high sulphur content, readily gives rise to the gaseous compounds of sulphur in smoke, while smoke arising from the combustion of eastern coals and coke, crude oil or the low distillates of oil, contains little or no sulphur.

The quantity of carbon compounds present in stack discharges merely indicates the degree of activity which proceeds in the furnace, since the combustible base of all fuels consists of carbon.

105.42 Relation between Furnace Conditions and the Gaseous Constituents of Smoke: Furnace conditions, irrespective of the character of fuel, constitute a factor which influences the amount and character of the gaseous constituents of smoke emissions. Other things being equal, an efficient furnace in which combustion proceeds under most favorable conditions serves to convert all of the carbon in the fuel into carbon dioxid and the greater portion of the sulphur in the fuel into gaseous sulphur compounds.

The presence of carbon monoxid gives evidence of imperfect combustion, due either to a deficient supply of air or to the imperfect mixing of gases within the furnace.

TABLE CV. SUMMARY OF ANALYSES OF GASES EMITTED IN SMOKE, ALL SERVICES

Service	Kind of Fuel	Kind of Gas in Per Cent of Total						
		Carbon Dioxid	Carbon Monoxid	Oxygen	Nitrogen	Sulphur Dioxid	Sulphur Trioxid	Total
1	2	3	4	5	6	7	8	9
Steam Locomotives:								
Yard	Poc.	*11.6	*0.2	*6.6	*81.5119	*0.0608	*0.0273	*100
	Bit.	11.6	0.2	6.6	81.5119	0.0608	0.0273	100
Road freight	Bit.	11.8	0.2	6.5	81.4165	0.0569	0.0266	100
Freight transfer	Poc.	*11.7	*0.2	*6.5	*81.5134	*0.0507	*0.0269	*100
	Bit.	11.7	0.2	6.5	81.5134	0.0507	0.0269	100
Passenger transfer	Poc.	11.6	*0.1	*6.7	*81.5025	*0.0684	*0.0291	*100
	Bit.	11.6	0.1	6.7	81.5025	0.0684	0.0291	100
Through passenger	Poc.	*12.3	*1.0	*5.2	*81.4273	*0.0417	*0.0310	*100
	Bit.	12.3	1.0	5.2	81.4273	0.0417	0.0310	100
Suburban passenger	Bit.	12.1	0.6	5.9	81.3250	0.0481	0.0269	100
Locomotive terminals	Bit.	*11.6	*0.1	*6.7	*81.5025	*0.0684	*0.0291	*100
Steam Vessels	Anth.	*1.2	*0.8	*18.0	*79.9962	*0.0003	*0.0035	*100
	Poc.	7.7	7.3	1.1	83.8669	0.0202	0.0129	100
	Bit.	10.7	4.2	2.1	82.9503	0.0216	0.0281	100
High Pressure Steam Stationary Power and Heating Plants	Anth.	*1.2	*0.8	*18.0	*79.9962	*0.0003	*0.0035	*100
	Coke	*1.2	*0.8	*18.0	*79.9962	*0.0003	*0.0035	*100
	Poc.	3.9	0	16.0	80.0885	0.0007	0.0108	100
	Bit.	3.0	0.2	16.1	80.6830	0.0006	0.0164	100
Low Pressure Steam and Other Stationary Heating Plants	Anth.	2.3	0.4	17.1	80.1955	0.0012	0.0033	100
	Coke	*1.2	*0.8	*18.0	*79.9962	*0.0003	*0.0035	*100
	Poc.	2.4	0.2	16.9	80.4937	0.0023	0.0040	100
	Bit.	4.5	0.7	14.2	80.5715	0.0059	0.0226	100
Gas and Coke Plants	Anth. Coke Poc. Bit.	No Tests Made						
Furnaces for Metallurgical, Manufacturing and Other Processes: Steel plants, foundries, forges and other allied processes	Anth.	4.0	0	15.6	80.3992	0.0004	0.0004	100
	Coke	11.9	0.8	9.1	78.1898	0.0042	0.0060	100
	Poc.	*7.7	*7.3	*1.1	*83.8669	*0.0202	*0.0129	*100
	Bit.	8.2	0.1	10.1	81.5701	0.0097	0.0202	100
Brick, pottery and other allied processes	Coke	*4.0	* 0	*15.6	*80.3992	*0.0004	*0.0004	*100
	Poc.	*7.7	*7.3	*1.1	*83.8669	*0.0202	*0.0129	*100
	Bit.	5.0	0.3	15.0	79.6426	0.0043	0.0531	100
Miscellaneous manufacturing, rendering and other processes	Anth.	1.2	0.8	18.0	79.9962	0.0003	0.0035	100
	Coke	*4.0	* 0	*15.6	*80.3992	*0.0004	*0.0004	*100
	Poc.	*7.7	*7.3	* 1.1	*83.8669	*0.0202	*0.0129	*100
	Bit.	*8.2	*0.1	*10.1	*81.5701	*0.0097	*0.0202	*100

* Values adapted from determinations made under similar conditions.

In the case of furnaces used for metallurgical, manufacturing and other industrial processes, it frequently occurs that gaseous constituents which have their origin in the materials under treatment appear in the smoke along with those of fuel origin.

An attempt to trace a relation between the composition of the gaseous products of combustion in smoke and the visibility of smoke is beset by many limitations. In general, it may be said that furnaces fired with Illinois coal, the smoke emissions of which show a relatively low visible density, discharge gases which are high in carbon dioxid and relatively high in sulphur dioxid and sulphur trioxid or their acid equivalents.

The introduction of relatively large quantities of air either through the grate, or into the combustion chamber or the smoke-stack, will, within certain limits, effect a reduction in the visibility of smoke discharges.

105.43 The Effect of Steam or Moisture upon the Character of the Gaseous Constituents of Smoke: The introduction of steam into the furnace or the intermixing of moisture with the gases of combustion, tends to hasten the conversion of the sulphur compounds into sulphuric acid. The use of steam jets, therefore, either in the furnace or in the stack, has a pronounced effect upon the character of the sulphur gases discharged. Steam jets are used extensively in locomotive service. They form an effective means of suppressing visible smoke. Their use and the fact that the products of combustion intermingle with the exhaust steam from the cylinders of the engine, augment the amount of sulphuric acid in the smoke discharges from locomotives. With reference to this constituent of smoke, therefore, the discharges from locomotives are not comparable with those from any other class of service investigated. The fact also that the gaseous products of combustion from locomotives are discharged near the ground, makes much more apparent the sulphurous content of locomotive smoke than that which is incident to the smoke of most other fuel consuming services.

105.44 Relation between Excess Air and the Gaseous Constituents of Smoke: The total volume of gases discharged from chimneys and stacks is increased by the presence of air in amounts which are in excess of those required for combustion. This excess air may be admitted through the furnace or introduced into the combustion chamber or into the stack. Excess air, by lowering the temperature of the furnace, has a pronounced effect upon furnace efficiency. It affects smoke discharges just as clear water affects a turbid mixture; it reduces the visibility of the smoke and, volume for volume, lowers the polluting effect thereof.

A deficient supply of air in the furnace tends to increase the quantity of carbon monoxid and to decrease the quantity of carbon dioxid and sulphur gases.

The Committee's study of smoke discharges shows that the prevailing practice in the operation of furnaces involves the use of large percentages of excess air. The smoke discharges of steam vessels contain least air and may be designated, therefore, as of maximum concentration; those of locomotives follow next in the order of concentration; and those of low pressure steam boilers and domestic fires are the least concentrated. In certain metallurgical processes, large volumes of excess air are employed as a means whereby oxidizing flame may be secured. The facts as disclosed by the Committee's researches with reference to this important element in smoke are summarized as follows:

	PER CENT OF AIR IN SMOKE
Steam locomotives	32.15
Steam vessels	10.95
High pressure steam boiler plants	80.44
Low pressure boiler plants and domestic fires	81.42
Metallurgical plants	48.45

The values given are based upon samples taken from the stack. There is a probability that, in many cases, such samples show a higher excess of air than would be disclosed by a sample taken from the furnace, the differences being due to leakage of air through the furnace setting, the smoke connections with the stack and portions of the stack itself.

It is apparent that any discussion concerning the effect of smoke as a polluting agency in the atmosphere must deal with its chemical properties as well as with its visible and physical properties. The discharge of a given volume of concentrated products of combustion will have a greater polluting effect than the discharge of a similar volume of air diluted products of combustion. In recognition of this fact all comparisons which are hereinafter presented, involving measures of the polluting effects of the gaseous products of combustion, exclude the excess air; that is, the polluting effects are not based upon the volume of smoke discharges but upon the volume of the gaseous products of combustion.

105.45 Gaseous Products of Combustion as Sources of Atmospheric Pollution: Notwithstanding the large volume of gaseous products of combustion which are emitted into the atmosphere of a city, little trace of them is disclosed by a chemical analysis of the atmosphere (chapter 113). The explanation is, of course, to be found in the fact that while the volume of the polluting discharge is great, that of the atmosphere affected is vastly greater and its power of absorbing and diffusing the streams of pollution which enter it is also great. The following illustration will prove serviceable in increasing one's understanding of this aspect of the matter.

The total volume of air diluted gases discharged each day from the stacks of Chicago amounts approximately to 47,000,000,000 cubic feet. The average wind velocity recorded in the city during the year 1912 was 13 miles an hour. The area of the city is 194 square miles. Assuming that the diluted gaseous products of combustion rise uniformly over this area as from an orifice and are borne away in a horizontal film by the wind, the thickness of the film at any given time would be approximately one-third of an inch. But the smoke discharges making up this film are air diluted, and if the air is extracted the thickness of the film would be reduced by 75 per cent; that is, the film of the gaseous products of combustion becomes approximately eight-hundredths of an inch in thickness. It will, of course, be understood that no such film actually exists, since the diffusion of the products of combustion into the atmosphere begins as soon as they are discharged; but the capacity of the atmosphere to absorb these gases can be better comprehended when one considers that its duty is that of continuously absorbing through diffusion a horizontal film or stratum of the gaseous products of combustion less than one-tenth of an inch in thickness.

CONCLUSIONS

105.46 Conclusions: The Committee's study of smoke discharges in the Area of Investigation justifies the following conclusions:

1. Visible Properties of Smoke:

a. Studies of visible smoke have led to the determination of a smoke density factor for each fuel consuming service (section 105.02), which factor, taken in connection with the amount of fuel consumed by the service, has permitted the different fuel consuming services to be rated on the basis of their relative contribution to the visible smoke of the city (section 105.06). The services recognized and the proportion of the total visible smoke contributed by each service in the city of Chicago are as follows:

	PER CENT
Steam locomotives	22.06
Steam vessels	0.74
High pressure steam stationary power and heating plants	44.49
Low pressure steam and other stationary heating plants	3.93
Gas and coke plants	0.15
Furnaces for metallurgical, manufacturing and other processes	28.63
	100.00

b. The production of visible smoke depends primarily upon the character of the fuel used. Assuming the use of Illinois coal, it is affected by the length of flameway, by draft, by rates of combustion and by the temperature of the furnace. It is affected also by the amount of excess air in the furnace. Smoke abatement is, under normal conditions, promoted by the use of brick arches and automatic stokers and by the exercise of care in the process of firing.

c. Other things being equal, it is easier to abate visible smoke from large fires than from small fires.

d. The loss in furnace efficiency attending the production of visible smoke is normally not great.

e. Visibility, considered alone, constitutes an insufficient basis upon which to measure the extent of atmospheric pollution by smoke.

2. Solid Constituents of Smoke:

a. The solid constituents of smoke, including soot, cinders and dust of varying composition, probably constitute the most important sources of atmospheric pollution arising from the combustion of fuel. The amount of the solid constituents of smoke discharged into the atmosphere of Chicago has been determined (section 105.29). The relative importance of the different fuel consuming services as producers of solid constituents of smoke in the city of Chicago is as follows:

	PER CENT
Steam locomotives	7.47
Steam vessels	0.33
High pressure steam stationary power and heating plants	19.34
Low pressure steam and other stationary heating plants	8.60
Gas and coke plants	0.00
Furnaces for metallurgical, manufacturing and other processes	64.26
	100.00

b. Not all the solids in smoke are of fuel origin. Of the total discharges of solid constituents of smoke into the atmosphere of Chicago, 41 per cent are of non-fuel origin. These arise from furnaces used in metallurgical, manufacturing and other processes.

c. All smoke arising from the combustion of solid fuels carries its burden of solids. The extent and character of the solid constituents are affected by various furnace conditions, especially by draft, rate of combustion and temperature of furnace. The fuel value of solids in smoke, under conditions which normally prevail, is small.

d. The absence of visibility in smoke does not imply the absence of the solid constituents of smoke.

e. The polluting effect of the solid constituents of smoke depends upon the size and the character of the particles emitted. The solids discharged by slow burning, low temperature fires consist largely of hydrocarbons carrying a large percentage of soot; solids from high temperature fires contain little or no soot but are high in carbon and ash.

3. Gaseous Constituents of Smoke:

a. The gaseous products of combustion consist of carbon and sulphur compounds and nitrogen (section 105.39). The extent of the sulphur gases is dependent upon the composition of the fuel. Smoke resulting from the burning of Illinois coal is relatively high in sulphur. The relative importance of the different fuel consuming services as producers of the gaseous products of combustion in smoke in the city of Chicago is as follows:

	PER CENT
Steam locomotives	10.31
Steam vessels	0.60
High pressure steam stationary power and heating plants	44.96
Low pressure steam and other stationary heating plants	23.00
Gas and coke plants	00.00
Furnaces for metallurgical, manufacturing and other processes	21.13
	100.00

b. The relative importance of the different fuel consuming services as producers of gaseous carbon constituents of smoke in the city of Chicago is as follows:

	PER CENT
Steam locomotives	10.11
Steam vessels	0.55
High pressure steam stationary power and heating plants	40.68
Low pressure steam and other stationary heating plants	23.06
Gas and coke plants	00.00
Furnaces for metallurgical, manufacturing and other processes	25.60
	100.00

c. The relative importance of the different fuel consuming services as producers of gaseous sulphur constituents of smoke in the city of Chicago is as follows:

	PER CENT
Steam locomotives	18.22
Steam vessels	0.45
High pressure steam stationary power and heating plants	53.70
Low pressure steam and other stationary heating plants	19.73
Gas and coke plants	00.00
Furnaces for metallurgical, manufacturing and other processes	7.90
	100.00

d. The gaseous content of smoke consists of the gaseous products of combustion and of air. The effect of air in smoke is to dilute the products of combustion. This dilution is least in the case of smoke from steam vessels and from locomotives, and is greatest in smoke from domestic fires.

e. The air dilution of the products of combustion tends to lower the visibility of smoke, and promotes a diffusion of the products of combustion in the atmosphere. The total volume of the products of combustion as compared with the volume of air moving over the city, by which it is absorbed, is very small.

106. THE RELATIVE IMPORTANCE OF THE STEAM LOCOMOTIVE AS A SOURCE OF SMOKE

SYNOPSIS: This chapter presents a series of comparisons which serve to measure the amount of smoke discharged by locomotives operating within the city of Chicago, in terms of the total smoke arising from all solid fuel fires within the city. Its purpose is to emphasize a single service by comparing it with all other services.

106.01 Purpose of this Study: The relative importance of various fuel consuming services as producers of smoke has been set forth in detail in the preceding chapter (105), which presents data developed by the Committee's investigation concerning the origin and character of smoke, its prime purpose being to establish a record of ascertained facts. It is the Committee's purpose in the present chapter, and in those immediately following, to direct attention to the contributions made by individual services to the smoke of Chicago's atmosphere, in their relation to the contributions of all other services combined. The present chapter deals with locomotive smoke in its relation to smoke from all other services.

106.02 Fuel Consumption of Steam Locomotives: The amount of smoke discharged into the atmosphere by any service is a function of the quantity of fuel consumed in that service, and the character of the smoke discharged is dependent to some extent upon the character of the fuel. Of the total quantity of fuel consumed by locomotives within the city of Chicago, more than 98 per cent consists of bituminous coal, practically all of which comes from the fields of Illinois and Indiana. A small amount of semi-bituminous or Pocahontas coal is burned in locomotives, chiefly in passenger services and under special conditions. For the purpose of this discussion, therefore, it may be assumed that all of the fuel consumed by locomotives consists of bituminous coal, the amount of semi-bituminous coal being regarded as negligible.

The relative importance of the steam locomotive on the basis of the quantity of fuel consumed, as compared with that consumed by all other services within the city, during the year 1912, is shown by the following:

	TONS	PER CENT
By steam locomotives	2,099,044	11.94
By all other services	15,483,479	88.06
Total for Chicago	17,582,523	100.00

Steam locomotive service ranks fourth among the six classes of fuel consuming services in the city of Chicago.

That portion of the total quantity of coal consumed, in 1912, within the city by all services, which is chargeable to the different locomotive services, is shown by the following:

	PER CENT OF TOTAL FOR ALL SERVICES	
Yard	5.97	
Road freight	0.77	
Freight transfer	2.02	
Passenger transfer	0.12	
Through passenger	1.01	
Suburban passenger	0.88	
Locomotives at locomotive terminals	1.17	
Total for steam locomotives		11.94
Total for all other services		88.06
Total all services		100.00

The extent to which locomotives constitute a source of atmospheric pollution is dependent not alone upon the relative quantity of fuel consumed but upon other factors incident to the conditions under which they operate. The effect of all such factors is to be seen in the following.

106.03 Visible Smoke from Locomotives: Visibility as a quality of smoke has reference to that property which renders smoke emissions apparent to the eye. It suggests the cloud effects of smoke discharges and the interception of sunlight by these smoke clouds. A standard of measure of visibility is supplied by an arbitrary scale, commonly referred to as the Ringelmann scale (section 105.02), with which the smoke to be observed may be compared. As a result of the Committee's investigations, it has been determined that the relative importance of the steam locomotive, on the basis of the total amount of visible smoke produced in the city of Chicago, is as follows:

	PER CENT
Visible smoke produced by steam locomotives	22.06
Visible smoke produced by all other services	77.94
Total	100.00

While steam locomotives operating within the city of Chicago consume approximately 12 per cent of the total amount of fuel consumed in the city, they produce 22 per cent of the total visible smoke. On this basis steam locomotives rank third among the six classes of smoke producing services in Chicago.

That portion of the total visible smoke of Chicago which is chargeable to the different locomotive services is as follows:

	PER CENT OF TOTAL FOR ALL SERVICES	
Yard	10.25	
Road freight	2.01	
Freight transfer	4.59	
Passenger transfer	0.19	
Through passenger	2.07	
Suburban passenger	1.54	
Locomotives at locomotive terminals	1.41	
Total for steam locomotives		22.06
Total for all other services		77.94
Total all services		100.00

There are within the city of Chicago 118 track establishments sufficiently extensive to be classified as yards, in and about which several hundred locomotives perform daily service. These locomotives contribute 10.25 per cent of the visible smoke discharged into the atmosphere of Chicago.

The road freight service and the freight transfer service in the city involve the activities of fewer locomotives than does the yard service, but a somewhat greater total amount of work, as measured by ton mileage, is performed by them. These services combined contribute 6.6 per cent of the visible smoke discharged into the atmosphere of Chicago.

The suburban passenger service contributes 1.54 per cent of the visible smoke, and all passenger services, including the suburban, through and transfer services, contribute 3.8 per cent of the visible smoke emitted into the atmosphere of Chicago.

There are 46 locomotive engine-houses, containing 891 stalls, within the city limits. Locomotives in these roundhouses contribute 1.41 per cent of the total visible smoke discharged into the atmosphere of Chicago.

106.04 Solid Constituents of Smoke Discharges from Steam Locomotives: All smoke from fires sustained by solid fuel carries a certain burden of solid constituents. This solid material may have the form of particles of ash, particles of partially consumed fuel or sooty particles. The investigations of the Committee show that the solid constituents in the smoke discharges of steam locomotives are chiefly in the form of ash and unconsumed fuel. There is comparatively little soot in the smoke of locomotives. A considerable portion of the solids emitted in the smoke of locomotives is of such character that it falls at no great distance from the track upon which the locomotive is proceeding; that is, considerable portions of the solids from locomotives constitute a source of local pollution rather than a source from which pollution pervades the atmosphere of the entire city (see Appendix, sections 701.37 to 701.43 inclusive).

The solid constituents of the smoke discharges of steam locomotives during the year 1912 in the city of Chicago amounted to 22,750 tons, consisting of the following:

	TONS	PER CENT
Coarse cinders	4,308.9	18.94
Fine cinders	12,174.6	53.51
Fuel dust	6,266.5	27.55
Total	22,750.0	100.00
Hydrocarbons (tarry matter)	117.1	0.51
Combustible solids (carbon)	12,594.4	55.36
Mineral matter (ash)	9,479.1	41.67
Sulphur	559.4	2.46
Total	22,750.0	100.00

The solid constituents of the smoke discharges of steam locomotives are chiefly in the form of ash and unconsumed fuel or combustible solids. The percentage of sooty materials is low, as is shown by the determinations for hydrocarbons.

The Committee's investigations show the following as to the amount of solids annually discharged in the smoke of steam locomotives and in that of all other services in Chicago:

	TONS	PER CENT
Solid constituents of the smoke of locomotives	22,750	7.47
Solid constituents of the smoke of all other services	281,641	92.53
Total	304,391	100.00

On this basis, steam locomotives rank fourth among the six classes of smoke producers in Chicago.

That portion of the total solid constituents of the smoke of all services, which is chargeable to the several locomotive services, is as follows:

	PER CENT OF TOTAL FOR ALL SERVICES	
Yard	1.73	
Road freight	1.18	
Freight transfer	0.43	
Passenger transfer	0.04	
Through passenger	1.80	
Suburban passenger	1.97	
Locomotives at locomotive terminals	0.32	
Total for steam locomotives		7.47
Total for all other services		92.53
Total all services		100.00

The preceding results indicate that locomotives in yard service contribute 1.73 per cent of the solid constituents of smoke discharged into the atmosphere of Chicago.

The road freight service and the freight transfer service combined contribute 1.61 per cent of the solid constituents of smoke discharged into the atmosphere of Chicago.

The suburban passenger service contributes 1.97 per cent of the solid constituents of smoke discharged into the atmosphere of Chicago, and all passenger services, including suburban, through and transfer services, contribute 3.81 per cent.

Locomotives at locomotive terminals within the city limits contribute 0.32 per cent of all the solid constituents of smoke discharged into the atmosphere of Chicago.

The chemical composition of the solid constituents of smoke from all classes of steam locomotives operating in the city of Chicago is shown by table CVI.

TABLE CVI. CHEMICAL COMPOSITION OF SOLID CONSTITUENTS OF SMOKE FROM ALL CLASSES OF STEAM LOCOMOTIVES. CITY OF CHICAGO

Class of Service	Per Cent of Total for All Services			
	Hydro-Carbons (Tar)	Combustible Solids (Carbon)	Mineral Matter (Ash)	Sulphur
1	2	3	4	5
Yard	0.27	3.09	1.34	3.36
Road freight	0.19	3.18	0.60	2.22
Freight transfer	0.06	0.86	0.32	0.70
Passenger transfer	0.01	0.07	0.03	0.07
Through passenger	0.21	4.94	0.90	3.17
Suburban passenger	0.20	5.74	0.87	3.42
Locomotives at locomotive terminals	0.05	0.56	0.25	0.65
Total for steam locomotives	0.99	18.44	4.31	13.59
Total for all other services	99.01	81.56	95.69	86.41
Total all services	100.00	100.00	100.00	100.00

106.05 Gaseous Constituents of Smoke Discharges from Steam Locomotives: The gaseous constituents of smoke consist of carbon dioxid, carbon monoxid, sulphur dioxid, sulphur trioxid and air. The sulphur and carbon compounds are to be regarded as polluting gases in the atmosphere. The air accompanying the gaseous products of combustion in the smoke discharges contains more than the normal proportion of nitrogen, owing to the depletion of the oxygen content, part of which combines with the carbon and sulphur in the fuel to form the carbon and sulphur compounds mentioned. This excess of nitrogen may be regarded as effecting a dilution of the atmosphere, and it is included with the carbon and sulphur compounds as a gaseous product of combustion.

The volume of each of the gases emitted into the atmosphere by each of the several fuel consuming services was determined by processes which have already been described (section 105.37). The volume of the gaseous products of combustion discharged annually into the atmosphere of Chicago by steam locomotives and by all fuel consuming services of the city is as follows:

	CUBIC FEET	PER CENT
Gases of combustion contained in the smoke of locomotives	427,341,334,935	10.31
Gases of combustion contained in the smoke of all other services	3,718,334,002,783	89.69
Total	4,145,675,337,718	100.00

Upon this basis, steam locomotives rank fourth among the six classes of smoke producing services in Chicago.

That portion of the total gases of combustion discharged into the atmosphere of Chicago annually by all services, which is chargeable to the different locomotive services, is as follows:

	PER CENT OF TOTAL FOR ALL SERVICES	
Yard	5.17	
Road freight	0.66	
Freight transfer	1.74	
Passenger transfer	0.10	
Through passenger	0.89	
Suburban passenger	0.74	
Locomotives at locomotive terminals	1.01	
Total for steam locomotives		10.31
Total for all other services		89.69
Total all services		100.00

The preceding results indicate that locomotives in yard service contribute 5.17 per cent of the total volume of the gaseous products of combustion discharged in the form of smoke into the atmosphere of Chicago.

Locomotives in road freight service and in freight transfer service combined contribute 2.40 per cent of the gaseous products of combustion in the smoke discharged into the atmosphere of Chicago.

Locomotives in suburban passenger service contribute 0.74 per cent of the total gaseous products of combustion in the smoke discharged into the atmosphere of Chicago, and locomotives in all passenger services, including suburban, through and transfer services, contribute 1.73 per cent.

Locomotives at locomotive terminals within the city limits contribute 1.01 per cent of all the gaseous products of combustion in the smoke discharged into the atmosphere of Chicago.

106.06 Relative Importance of the Steam Locomotive as a Smoke Producer, on Each of the Bases Considered: The extent to which the steam locomotive contributes to the pollution of the atmosphere of the city of Chicago on the basis of fuel consumed, visible smoke, solid constituents of smoke and gaseous constituents of smoke, is shown diagrammatically by fig. 29.

106.07 Conclusions to be Drawn with Reference to the Extent to which Smoke Discharges from Steam Locomotives Pollute the Atmosphere of Chicago: This study of the results of the Committee's numerous tests and analyses, made in connection with the investigation of smoke discharges, justifies the following conclusions with reference to the extent to which the smoke discharges from steam locomotives constitute a source of atmospheric pollution:

1. Steam locomotives consume 11.94 per cent of the total fuel consumed within the city limits of Chicago, and they rank fourth as a fuel consuming service.

2. Steam locomotives are responsible for 22.06 per cent of the total visible smoke discharged within the city limits of Chicago, and they rank third among all services on the basis of total quantity of visible smoke produced.

3. Steam locomotives are responsible for 7.47 per cent of the total solid constituents discharged into the atmosphere in the smoke of all services within the city limits of Chicago, and they rank fourth among all services on the basis of the total amount of solid materials discharged into the atmosphere in smoke.

4. Steam locomotives are responsible for 10.31 per cent of the total gases of combustion discharged into the atmosphere in the smoke of all services within the city limits of Chicago, and they rank fourth as a service producing polluting gases discharged into the atmosphere in smoke.

5. The contributions made by the different classes of steam locomotives to the pollution of the atmosphere of Chicago are as follows:

a. Locomotives engaged in suburban passenger service contribute 1.54 per cent of the total visible smoke, 1.97 per cent of the total dust and cinders of smoke and 0.74 per cent of the total polluting gases of smoke discharged annually into the atmosphere of Chicago.

b. Locomotives engaged in through passenger service contribute 2.07 per cent of the total visible smoke, 1.80 per cent of the total dust and cinders of smoke and 0.89 per cent of the total polluting gases of smoke discharged annually into the atmosphere of Chicago.

c. Locomotives engaged in all passenger services combined, including suburban passenger, through passenger and passenger transfer, contribute 3.80 per cent of the total visible smoke, 3.81 per cent of the total dust and cinders of smoke and 1.73 per cent of the total polluting gases of smoke discharged annually into the atmosphere of Chicago.

d. Locomotives engaged in road freight service contribute 2.01 per cent of the total visible smoke, 1.18 per cent of the total dust and cinders of smoke and 0.66 per cent of the total polluting gases of smoke discharged annually into the atmosphere of Chicago.

e. Locomotives engaged in yard freight service contribute 10.25 per cent of the total visible smoke, 1.73 per cent of the total dust and cinders of smoke and 5.17 per cent of the total polluting gases of smoke discharged annually into the atmosphere of Chicago.

f. Locomotives engaged in all freight services, including road freight, yard freight and freight transfer services, contribute 16.85 per cent of the total visible smoke, 3.34 per cent of the total dust and cinders of smoke and 7.57 per cent of the total polluting gases of smoke discharged annually into the atmosphere of Chicago.

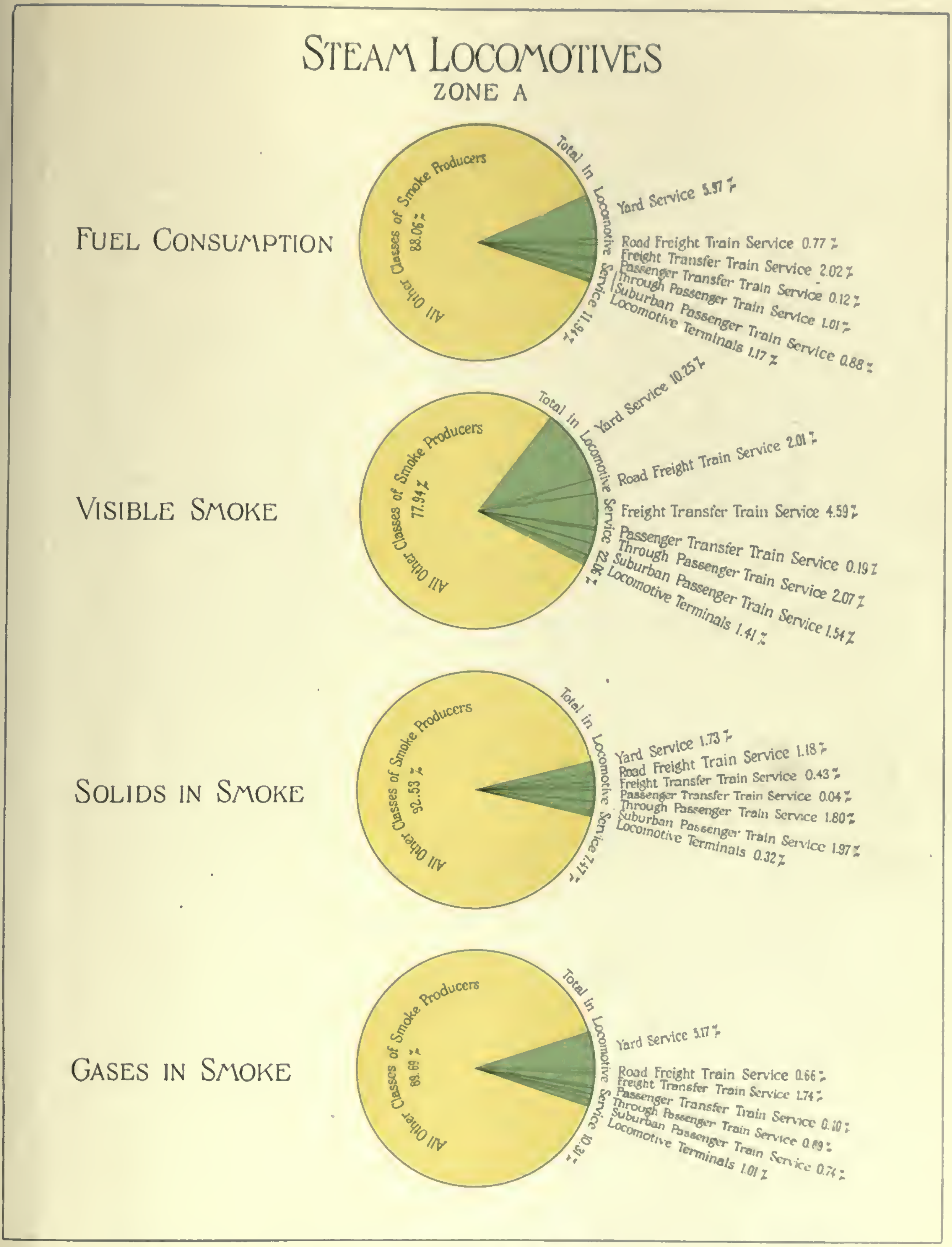

FIG. 29. RELATIVE IMPORTANCE OF STEAM LOCOMOTIVES AS A FUEL CONSUMING AND SMOKE PRODUCING SERVICE

107. THE RELATIVE IMPORTANCE OF STEAM VESSELS AS A SOURCE OF SMOKE

SYNOPSIS: This chapter presents a series of comparisons which serve to measure the amount of smoke discharged by steam vessels operating within the city of Chicago, in terms of the total smoke arising from all solid fuel fires within the city. Its purpose is to emphasize a single service by comparing it with all other services.

107.01 Purpose of this Study: The data developed by the Committee's investigation concerning the origin and character of smoke have been presented in chapter 105, in which a record of ascertained facts is established. It is the Committee's purpose in this chapter to emphasize the contributions to the smoke of Chicago's atmosphere which are made by steam vessels, and to set forth the relation between the smoke from steam vessels and that from all other services. The term "steam vessels," as employed in the study, embraces all kinds of water craft operated by steam on waterways within the city limits of Chicago, including tugs, lighters, river dredges, pile-drivers, lake steamers and lake barges.

107.02 Fuel Consumption of Steam Vessels: During the year 1912, there were 5,751 steam vessels which entered the ports of Chicago and South Chicago and, in addition to these, 119 which remained in the city and its vicinity throughout the year. The smoke produced by these vessels while operating in the harbors and along the inland waterways, and also that produced by them while operating along the shores of the lake between the northern and southern limits of the city, were included in the Committee's determinations.

The amount and character of the smoke discharged into the atmosphere by steam vessels is dependent to some extent upon the quantity and character of the fuel consumed by them. During the year 1912, steam vessels within the city limits of Chicago consumed approximately 81,000 tons of coal, of which a total of 76,000 tons was bituminous and 5,000 tons semi-bituminous.

The relative importance of steam vessels within the city limits, on the basis of the total fuel annually consumed, as compared with that consumed by all other services, is shown by the following:

	TONS	PER CENT
By steam vessels	81,375	0.46
By all other services	17,501,148	99.54
Total	17,582,523	100.00

Steam vessels rank sixth and lowest as a fuel consuming service in the city of Chicago.

That portion of the total quantity of coal consumed annually within the city by all services, which is burned by the different classes of steam vessels, is as follows:

	PER CENT OF TOTAL FOR ALL SERVICES	
Tugs and lighters	0.20	
River barges, dredges and pile-drivers	0.06	
Lake steamers and barges	0.20	
Total for steam vessels		0.46
Total for all other services		99.54
Total all services		100.00

107.03 Visible Smoke from Steam Vessels: Visibility as a quality of smoke has reference to that property which renders smoke emissions apparent to the eye. It suggests the cloud effects of smoke discharges and the interception of sunlight by these smoke clouds. A standard measure of visibility is supplied by an arbitrary scale, shading from white to black, with which the smoke to be observed may be compared. This scale is commonly referred to as the Ringelmann scale (section 105.02). As a result of the Committee's investigation, it has been determined that the relative importance of the steam vessel, as a producer of visible smoke in the city of Chicago, is as follows:

	PER CENT
Visible smoke produced by steam vessels	0.74
Visible smoke produced by all other services	99.26
Total	100.00

On this basis steam vessels rank fifth among the smoke producing services in Chicago.

That portion of the total visible smoke of Chicago, which is chargeable to the different classes of steam vessels, is as follows:

	PER CENT OF TOTAL FOR ALL SERVICES	
Tugs and lighters	0.29	
River barges, dredges and pile-drivers	0.14	
Lake steamers and barges	0.31	
Total for steam vessels		0.74
Total for all other services		99.26
Total all services		100.00

107.04 Solid Constituents of Smoke Discharges from Steam Vessels: The solid constituents of the smoke discharges of steam vessels during 1912 amounted to 995 tons, as follows:

	TONS	PER CENT
Coarse cinders	64.8	6.5
Fine cinders	482.6	48.5
Fuel dust	447.6	45.0
Total	995.0	100.0
Combustible solids (carbon)	505.7	50.8
Mineral matter (ash)	456.0	45.8
Hydrocarbons (tarry matter)	26.9	2.7
Sulphur	6.4	0.7
Total	995.0	100.0

The solid constituents of the smoke discharges of steam vessels, like those of steam locomotives, are chiefly in the form of ash and unconsumed carbon. The percentage of sooty materials or materials condensed from the distillates of fuel is low, although considerably higher than that contained in the solids of locomotive smoke.

The Committee's investigations show the amount of solids annually discharged in the smoke of steam vessels, and in the smoke of all other services in Chicago, to be as follows:

	TONS	PER CENT
Solid constituents of the smoke of steam vessels	995	0.33
Solid constituents of the smoke of all other services	303,396	99.67
Total	304,391	100.00

On this basis steam vessels rank fifth and lowest among the smoke producing services of Chicago.

That portion of the total solid constituents of the smoke of all services chargeable to the several classes of steam vessels is as follows:

	PER CENT OF TOTAL FOR ALL SERVICES	
Tugs and lighters	0.14	
River barges, dredges and pile-drivers	0.05	
Lake steamers and barges	0.14	
Total for steam vessels		0.33
Total for all other services		99.67
Total all services		100.00

107.05 Gaseous Constituents of Smoke Discharges from Steam Vessels: The gaseous constituents of smoke consist of carbon dioxid, carbon monoxid, sulphur dioxid, sulphur trioxid and air. The carbon and sulphur compounds are to be regarded as polluting gases in the atmosphere. The air accompanying the gaseous products of combustion in the smoke discharges contains more than the normal proportion of nitrogen, owing to the depletion of the oxygen content, part of which combines with the carbon and sulphur in the fuel to form the carbon and sulphur compounds mentioned. This excess of nitrogen may be regarded as effecting a dilution of the atmosphere, and it is included with the carbon and sulphur compounds as a gaseous product of combustion.

The volume of the gaseous products of combustion, including nitrogen, discharged annually into the atmosphere of Chicago by steam vessels, and by all other fuel consuming services of the city, is as follows:

	CUBIC FEET	PER CENT
Gases of combustion contained in the smoke of steam vessels	24,767,392,653	0.60
Gases of combustion contained in the smoke of all other services	4,120,907,945,065	99.40
Total	4,145,675,337,718	100.00

Upon this basis the steam vessel ranks fifth and lowest among the smoke producing services of Chicago.

That portion of all the gaseous products of combustion discharged into the atmosphere of Chicago annually, which is chargeable to the different classes of steam vessels, has been shown to be as follows:

	PER CENT OF TOTAL FOR ALL SERVICES	
Tugs and lighters	0.26	
River barges, dredges and pile-drivers	0.08	
Lake steamers and barges	0.26	
Total for steam vessels		0.60
Total for all other services		99.40
Total all services		100.00

107.06 Relative Importance of the Steam Vessel as a Smoke Producer, on Each of the Bases Considered: The extent to which steam vessels contribute to the pollution of the atmosphere of the city of Chicago, on the basis of fuel consumed, visible smoke, solid constituents of smoke and gaseous constituents of smoke, is shown diagrammatically by fig. 30.

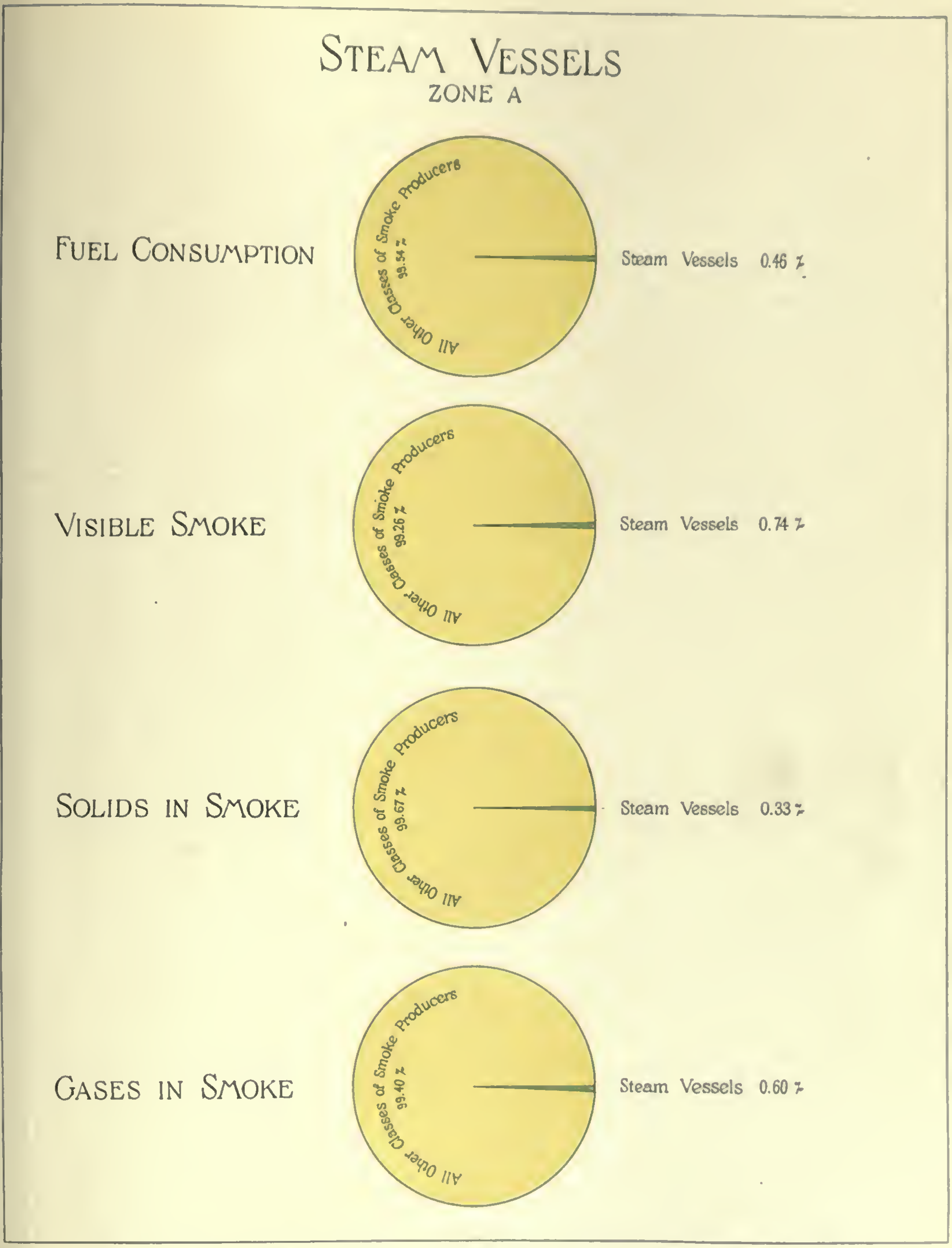

FIG. 30. RELATIVE IMPORTANCE OF STEAM VESSELS AS A FUEL CONSUMING AND SMOKE PRODUCING SERVICE

107.07 **Conclusions to be Drawn with Reference to the Extent to which Smoke Discharges from Steam Vessels Pollute the Atmosphere of Chicago:** This study of the results of the Committee's numerous tests and analyses, made in connection with the investigation of smoke discharges, justifies the following conclusions as to the extent to which the smoke discharges from steam vessels constitute a source of atmospheric pollution:

1. Steam vessels consume 0.46 per cent of the total amount of fuel consumed within the city limits of Chicago.

2. Steam vessels are responsible for 0.74 per cent of the visible smoke discharged within the city limits of Chicago.

3. Steam vessels are responsible for 0.33 per cent of the solid constituents of smoke discharged into the atmosphere within the city limits of Chicago.

4. Steam vessels are responsible for 0.60 per cent of the total gaseous products of combustion discharged into the atmosphere within the city limits of Chicago.

5. The contribution of steam vessels to the pollution of Chicago's atmosphere is, when compared with that of other services or with the total of all services, less important than the contribution of any other service.

108. THE RELATIVE IMPORTANCE OF HIGH PRESSURE STEAM STATIONARY POWER AND HEATING PLANTS AS A SOURCE OF SMOKE

SYNOPSIS: This chapter presents a series of comparisons which serve to measure the amount of smoke discharged by high pressure steam stationary power and heating plants operating within the city of Chicago, in terms of the total smoke arising from all solid fuel fires within the city. Its purpose is to emphasize the smoke of a single service by comparing it with that of all other services.

108.01 Purpose of this Study: The relative importance of various fuel consuming services as producers of smoke has been set forth in detail in chapter 105, which presents all of the data derived from the Committee's investigations regarding the origin and character of smoke. It is the Committee's purpose in the present chapter to emphasize the extent to which high pressure steam stationary power and heating plants contribute to the smoke of Chicago's atmosphere, as compared with the contribution of all other services combined.

108.02 Fuel Consumption of High Pressure Steam Stationary Power and Heating Plants: There are within the city of Chicago about 6,000 high pressure steam stationary power and heating plants, or plants in which a steam pressure of more than ten pounds is maintained in the boiler.

The extent to which these plants contribute to the smoke of the atmosphere is a function of the quantity of fuel consumed, and the character of the smoke discharged is dependent to some extent upon the composition of the fuel.

The relative importance of high pressure steam stationary power and heating plants as producers of smoke within the city of Chicago, on the basis of the quantity of fuel consumed in 1912, is as follows:

	TONS	PER CENT
By high pressure steam stationary power and heating plants	7,316,257	41.61
By other services	10,266,272	58.39
Total	17,582,529	100.00

High pressure steam stationary power and heating plants rank first as a fuel consuming service in the city of Chicago. The extent to which the furnaces of these plants constitute a source of atmospheric pollution is, however, dependent not alone upon the relative quantity of fuel consumed but upon other factors incident to the conditions under which they operate. The effect of all such factors is to be seen in the sections which follow.

108.03 Visible Smoke from High Pressure Steam Stationary Power and Heating Plants: Visibility as a quality of smoke has reference to that property which renders smoke emissions apparent to the eye. It suggests the cloud effects of smoke discharges and the effects of smoke in intercepting or reflecting the light of the sun. A standard of measure of visibility is supplied by an arbitrary scale shading from white to black, with which the smoke to be observed may be compared. This is commonly referred to as the Ringelmann scale (section 105.02). As a result of the Committee's investigations, it has been determined that the relative importance of high pressure steam stationary power and heating plants, on the basis of the total amount of visible smoke produced in Chicago, is as follows:

	PER CENT
Visible smoke produced by high pressure steam stationary power and heating plants	44.49
Visible smoke produced by all other services	55.51
Total	100.00

On this basis high pressure steam stationary power and heating plants rank first among the smoke producing services in Chicago. It is to be noted that the relative importance of this service, on the basis of the visible smoke produced, is almost the same as that on the basis of the quantity of fuel consumed, its proportion of the visible smoke produced being 44.49 per cent and that of the fuel consumed 41.61 per cent.

108.04 Solid Constituents of Smoke Discharges from High Pressure Steam Stationary Power and Heating Plants: All smoke from fires sustained by solid fuels carries a certain burden of solid constituents. These solid materials consist of particles of ash, particles of finely divided combustible materials and of sooty particles condensed from the distillates of fuel. The quantity and character of the solids discharged in smoke serve to indicate the extent to which the smoke discharge in question is responsible for the presence of dust, cinders and soot in the atmosphere. Owing to the finely divided state of the solids emitted in the smoke of high pressure steam stationary power and heating plants, the resulting pollution may be regarded as affecting wide areas, since such materials are easily carried by the wind and air currents. Chemical analyses of the solid materials emitted in the smoke of high pressure steam stationary power and heating plants indicate that the discharges contain 60 per cent of ash, 33 per cent of combustible carbon or particles of unconsumed fuel, 4 per cent of sooty materials condensed from the distillates of fuel, and 3 per cent of sulphur. High pressure steam stationary power and heating plants are responsible for 17 per cent of the total fuel dust, 30 per cent of the total fine cinders, 3 per cent of the coarse cinders, 16 per cent of the ash, 28 per cent of the particles of unconsumed fuel, 44 per cent of the sulphur and 21 per cent of the sooty materials, or hydrocarbons, discharged annually into the atmosphere of Chicago. Upon the basis of the total quantity of solids emitted into the atmosphere of the city of Chicago annually, the relative importance of high pressure steam stationary power and heating plants is as follows:

	TONS	PER CENT
Solid constituents of the smoke of high pressure steam stationary power and heating plants	58,867	19.34
Solid constituents of the smoke of all other services	245,524	80.66
Total	304,391	100.00

Upon this basis high pressure steam stationary power and heating plants rank second among the smoke producing services in Chicago.

The weight of the solid materials discharged by these plants, 58,867 tons, is equivalent to 0.805 per cent of the total fuel consumed in this service.

108.05 Gaseous Constituents of Smoke Discharges from High Pressure Steam Stationary Power and Heating Plants: The gaseous constituents of smoke consist of carbon monoxid, carbon dioxid, sulphur dioxid, sulphur trioxid and air. The carbon and sulphur compounds are to be regarded as polluting gases in the atmosphere. The air accompanying the gaseous products of combustion in the smoke discharges contains more than the normal proportion of nitrogen, owing to depletion of the oxygen content, part of which combines with the carbon and sulphur in the fuel to form the carbon and sulphur compounds mentioned. This excess of nitrogen may be regarded as effecting a dilution of the atmosphere, and it is included with the carbon and sulphur compounds as a gaseous product of combustion in determining the relative importance of the different services as producers of polluting gases. The excess air in the gaseous discharges from stacks is not considered in these computations. The volume of the gaseous products of combustion discharged annually into the atmosphere of Chicago by high pressure steam stationary power and heating plants and by all other fuel consuming services of the city is as follows:

	CUBIC FEET	PER CENT
Gases of combustion contained in the smoke of high pressure steam stationary power and heating plants	1,864,089,622,260	44.96
Gases of combustion contained in the smoke of all other services	2,281,585,715,458	55.04
Total	4,145,675,337,718	100.00

Upon this basis high pressure steam stationary power and heating plants rank first among the smoke producing services of Chicago. Since the gases discharged into the atmosphere by high pressure steam stationary power and heating plants are usually emitted from tall smoke-stacks and chimneys, they are probably not objectionable to the same extent as are the gases of combustion emitted at much lower altitudes from the stacks of other services.

108.06 Relative Importance of High Pressure Steam Stationary Power and Heating Plants as a Source of Smoke, on Each of the Bases Considered: The extent to which high pressure steam stationary power and heating plants contribute to the pollution of the atmosphere of the city of Chicago, on the bases of fuel consumed, visible smoke, solid constituents of smoke and gaseous constituents of smoke, is shown diagrammatically by fig. 31.

108.07 Conclusions to be Drawn with Reference to the Extent to which Smoke Discharges from High Pressure Steam Stationary Power and Heating Plants Pollute the Atmosphere of Chicago: This study of the results of the numerous tests and analyses made in connection with the investigation of smoke discharges in the city of Chicago, justifies the following conclusions with reference to the extent to which the smoke discharges from high pressure steam stationary power and heating plants constitute a source of atmospheric pollution:

1. High pressure steam stationary power and heating plants consume about 41.6 per cent of the total fuel consumed within the city limits of Chicago, and rank first as a fuel consuming service.
2. High pressure steam stationary power and heating plants are responsible for 44.49 per cent of the total visible smoke discharged within the city limits of Chicago, and rank first among all services on the basis of the total quantity of visible smoke produced.
3. High pressure steam stationary power and heating plants are responsible for 19.34 per cent of the total solid constituents discharged into the atmosphere in the smoke of all services within the city limits of Chicago, and rank second among all services on the basis of the total amount of solid materials discharged into the atmosphere in smoke.
4. High pressure steam stationary power and heating plants are responsible for 44.96 per cent of the total polluting gases of combustion discharged into the atmosphere in the smoke of all services within the city limits of Chicago, and rank first as a service producing polluting gases discharged into the atmosphere in smoke.

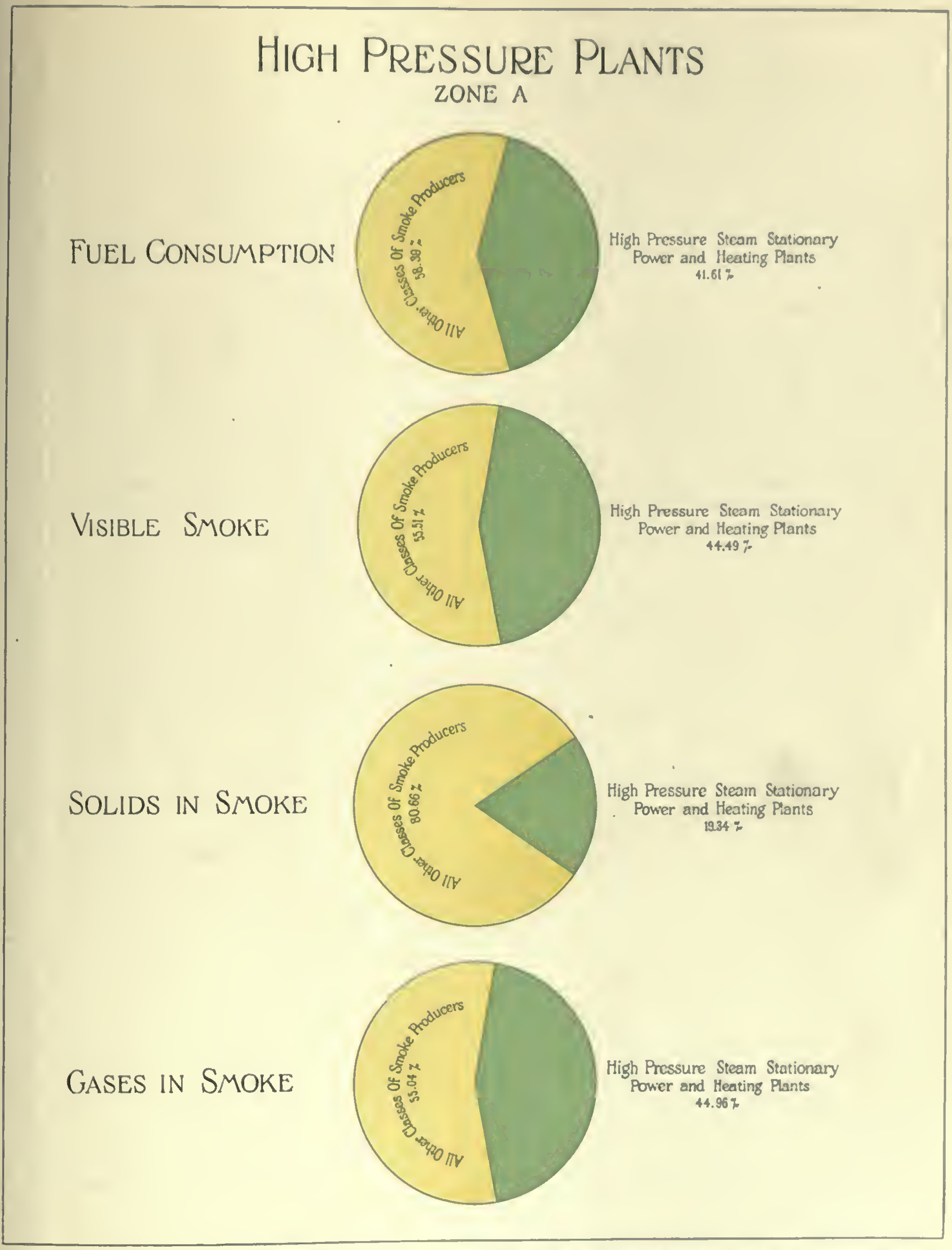

FIG. 31. RELATIVE IMPORTANCE OF HIGH PRESSURE STEAM STATIONARY POWER AND HEATING PLANTS AS A FUEL CONSUMING AND SMOKE PRODUCING SERVICE

[Facing p. 154]

109. THE RELATIVE IMPORTANCE OF LOW PRESSURE STEAM AND OTHER STATIONARY HEATING PLANTS AS A SOURCE OF SMOKE

SYNOPSIS: This chapter presents a series of comparisons which serve to indicate the amount of smoke discharged by low pressure steam and other stationary heating plants operating within the city of Chicago, in terms of the total smoke arising from all solid fuel fires within the city. Its purpose is to emphasize the smoke of a single service by comparing it with that of all other services.

109.01 Purpose of this Study: The relative importance of various fuel consuming services as producers of smoke, and all the data developed by the Committee's investigation concerning the origin and character of smoke, have already been presented (chapter 105). It is the Committee's purpose in the present chapter to emphasize the contributions to the smoke of Chicago's atmosphere which are made by low pressure steam and other stationary heating plants (including the smoke from domestic fires), in their relation to the contributions of smoke from all other services.

109.02 Fuel Consumption of Low Pressure Steam and Other Stationary Heating Plants: There are within the city of Chicago more than 11,000 low pressure steam boilers in which a steam pressure of less than ten pounds per square inch is maintained. There are also several hundred thousand domestic heating furnaces and stoves in houses and stores. In point of number of establishments, therefore, the service involved by the classification "low pressure steam and other stationary heating plants" is many times larger than any other service considered in the Committee's investigation. The various types of furnaces employed, the many different methods of firing used and the variety of fuels burned, all render this service more complex than any of the others considered. Any effort to abate the smoke from these fires involves, also, the attention of a much larger number of persons than is the case with any other service. The Committee's determinations, however, were made essentially along the same lines employed in connection with the other services.

The amount of smoke discharged into the atmosphere by low pressure steam and other stationary heating plants is a function of the quantity of fuel consumed in that service, and the character of the smoke discharged is dependent to some extent upon the character of the fuel. On the basis of the quantity of fuel consumed during the year 1912, the relative importance of low pressure steam and other stationary heating plants as a fuel consuming service within the city of Chicago, is as follows:

	TONS	PER CENT
By low pressure steam and other stationary heating plants	4,154,746	23.63
By all other services	13,427,777	76.37
Total	17,582,523	100.00

On this basis low pressure steam and other stationary heating plants rank second among the fuel consuming services in the city of Chicago. It should be noted, however, that this service ranks first in the consumption of anthracite coal, burning more than 96 per cent of the total amount of such fuel consumed within the city of Chicago. Approximately 38 per cent of the total amount of fuel consumed by low pressure steam and other stationary heating plants in Chicago consists of anthracite coal, about 41 per cent is bituminous coal, 20 per cent is semi-bituminous, and the remaining 1.0 per cent is coke. Another significant feature to be considered in connection with the fuel consumption of low pressure steam and other stationary heating plants lies in the fact that nearly all the fuel is burned during the winter months. That the character of the fuel has an important bearing upon the character of the constituents of the smoke is shown by the results set forth in the following sections. But these results also show that the extent to which low pressure steam and other stationary heating plants contribute to the pollution of the atmosphere by smoke discharges depends not alone upon the character and amount of fuel consumed but also upon other factors incident to the conditions under which the fuel is burned. The effect of all such factors is to be seen in the results.

109.03 Visible Smoke from Low Pressure Steam and Other Stationary Heating Plants: Visibility as a quality of smoke has reference to that property which renders smoke emissions suspended in the atmosphere apparent to the eye. It suggests the cloud effects of smoke discharges. As a result of the Committee's investigations, it has been determined that the relative importance of low pressure steam and other stationary heating plants, as producers of visible smoke in the city of Chicago, is as follows:

	PER CENT
Visible smoke produced by low pressure steam and other stationary heating plants	3.93
Visible smoke produced by all other services . . .	96.07
Total	100.00

On this basis low pressure steam and other stationary heating plants rank fourth as a smoke producing service in the city of Chicago. While this class of service consumes more than 23.5 per cent of the total amount of fuel consumed by all services combined, it contributes less than 4 per cent of the total visible smoke produced by all services within the city of Chicago. This low percentage of visible smoke is largely due to the character of fuel used, to the dilution of the smoke through the intermingling of large percentages of excess air and to the average low velocity at which gases pass from the stack into the atmosphere. This visibility is lower than that which attends the discharges from other services, and as a consequence the dissipation of the gases in the atmosphere proceeds more rapidly. Bituminous coals represent but 41 per cent of the total fuel consumed by low pressure steam and other stationary heating plants in the city of Chicago, and this bituminous coal produces practically all of the visible smoke emitted by this service.

109.04 Solid Constituents of Smoke Discharges from Low Pressure Steam and Other Stationary Heating Plants: Smoke from fires sustained by solid fuels contains solid constituents. This solid material may have the form of particles of ash, of particles of partially consumed fuel or of sooty particles condensed from the distillates of fuel. On the basis of the total quantity of such solid constituents in the smoke annually discharged into the atmosphere, the relative importance of low pressure steam and other stationary heating plants, as a smoke producing service in the city of Chicago, is as follows:

	TONS	PER CENT
Solid constituents of the smoke of low pressure steam and other stationary heating plants	26,180 . .	8.60
Solid constituents of the smoke of all other services	278,211 . .	91.40
Total	304,391 . .	100.00

On this basis low pressure steam and other stationary heating plants rank third among the smoke producing services in the city of Chicago.

The amount of each kind of fuel consumed by low pressure steam and other stationary heating plants, and the relative quantity of each of the solid constituents in the smoke discharges chargeable to each kind of fuel, are given in table CVII.

While anthracite coal constitutes 38 per cent of the total amount of fuel burned by low pressure steam and other stationary heating plants in Chicago, its contribution to the solid constituents of the smoke is low, amounting to only 0.138 per cent of the weight of fuel consumed. Bituminous coal, which constitutes about 41 per cent of the fuel consumed by low pressure steam and other stationary heating plants, is responsible for

TABLE CVII. SOLID CONSTITUENTS OF THE SMOKE OF LOW PRESSURE STEAM AND OTHER STATIONARY HEATING PLANTS. CITY OF CHICAGO

Kind of Fuel	Tons of Fuel Consumed	Tons of Solids by Physical Analyses			Tons of Solids by Chemical Analyses				Total Weight of Solids	Solids in Per Cent of Fuel Burned
		Coarse Cinders	Fine Cinders	Fuel Dust	Hydro-Carbons (Tar)	Combustible Solids (Carbon)	Mineral Matter (Ash)	Sulphur		
1	2	3	4	5	6	7	8	9	10	11
Coke	41,181	0	0	92.0	27.6	34.7	29.7	*	92.0	0.223
Anthracite	1,577,761	0	0	2,177.0	15.9	694.0	1,467.1	*	2,177.0	0.138
Semi-bituminous (Poc.) . .	849,185	0	628.4	3,532.6	475.6	2,284.4	1,392.7	8.3	4,161.0	0.490
Bituminous	1,686,619	0	1,450.5	18,299.5	6,207.4	8,701.9	4,368.7	472.0	19,750.0	1.171
Totals	4,154,746	0	2,078.9	24,101.1	6,726.5	11,715.0	7,258.2	480.3	26,180.0	. . . . .

*Less than 0.05 ton.

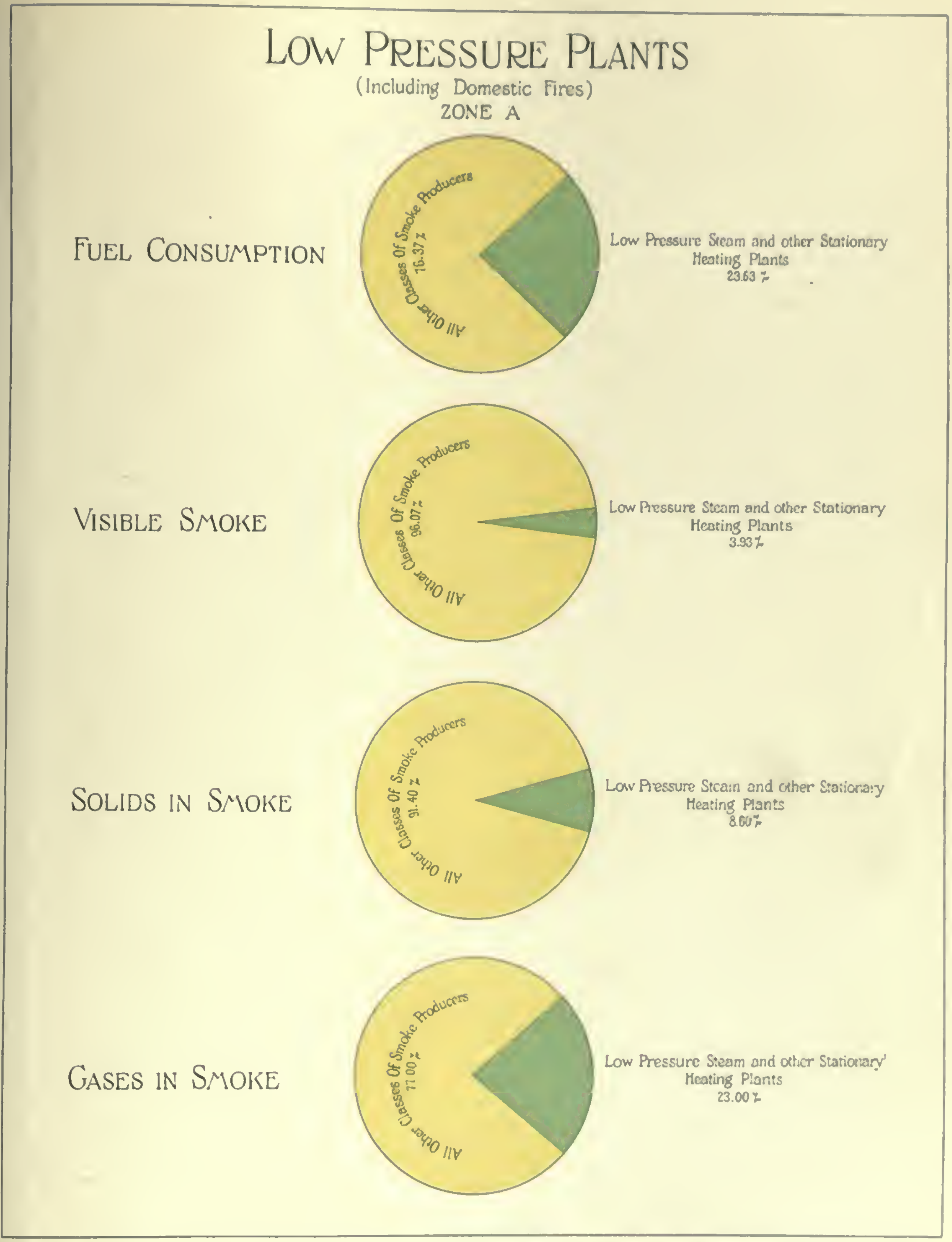

FIG. 32. RELATIVE IMPORTANCE OF LOW PRESSURE STEAM AND OTHER STATIONARY HEATING PLANTS AS A FUEL CONSUMING AND SMOKE PRODUCING SERVICE

[Facing p. 186]

approximately 70 per cent of the cinders, 76 per cent of the fuel dust, 92 per cent of the hydrocarbons (tar), 74 per cent of the combustible solids, 60 per cent of the mineral matter (ash), 98 per cent of the sulphur and more than 75 per cent of the total solids emitted in the smoke of this service.

From the standpoint of the total weight of hydrocarbons, low pressure steam and other stationary heating plants rank first, contributing 57 per cent of the total quantity of such materials emitted by all services into the atmosphere of the city of Chicago.

109.05 Gaseous Constituents of Smoke Discharges from Low Pressure Steam and Other Stationary Heating Plants: The gaseous constituents of smoke consist of carbon dioxid, carbon monoxid, sulphur dioxid, sulphur trioxid and air. The sulphur and carbon compounds are to be regarded as polluting gases in the atmosphere. The air accompanying the gaseous products of combustion in the smoke discharges contains more than the normal proportion of nitrogen owing to the depletion of the oxygen content, part of which combines with the carbon and sulphur in the fuel to form the carbon and sulphur compounds mentioned. This excess of nitrogen, may be regarded as effecting a dilution of the atmosphere, and it is included with the carbon and sulphur compounds as a gaseous product of combustion. The excess air discharged with these gases is not considered in making the determinations.

The volume of the gaseous products of combustion discharged annually into the atmosphere of Chicago by low pressure steam and other stationary heating plants, and by all other smoke producing services, is as follows:

	CUBIC FEET	PER CENT
Gases of combustion contained in the smoke of low pressure steam and other stationary heating plants	953,389,137,414	23.00
Gases of combustion contained in the smoke of all other services	3,192,286,200,304	77.00
Total	4,145,675,337,718	100.00

Upon this basis low pressure steam and other stationary heating plants rank second among the smoke producing services of Chicago.

109.06 Relative Importance of Low Pressure Steam and Other Stationary Heating Plants as Smoke Producers, on each of the Bases Considered: The extent to which low pressure steam and other stationary heating plants contribute to the pollution of the atmosphere of the city of Chicago, on the bases of fuel consumed, visible smoke, solid constituents of smoke and gaseous constituents of smoke, is shown diagrammatically by fig. 32.

109.07 Conclusions to be Drawn with Reference to the Extent to which Smoke Discharges from Low Pressure Steam and Other Stationary Heating Plants Pollute the Atmosphere of Chicago: The results of the Committee's numerous tests and analyses made in connection with the investigation of smoke discharges in the city of Chicago, justifies the following conclusions with reference to the extent to which the smoke discharges from low pressure steam and other stationary heating plants constitute a source of atmospheric pollution:

1. Low pressure steam and other stationary heating plants consume 23.63 per cent of the total fuel consumed within the city of Chicago.
2. Low pressure steam and other stationary heating plants are responsible for 3.93 per cent of the total visible smoke discharged within the city of Chicago.
3. Low pressure steam and other stationary heating plants are responsible for 8.60 per cent of the total solid constituents discharged into the atmosphere in the smoke of all services within the city of Chicago.
4. Low pressure steam and other stationary heating plants are responsible for about 57 per cent of the total hydrocarbons, or sooty materials condensed from the distillates of fuel, discharged into the atmosphere in the smoke of all services within the city of Chicago.
5. Low pressure steam and other stationary heating plants are responsible for 23 per cent of the total gases of combustion discharged into the atmosphere in the smoke of all services within the city of Chicago.

110. THE RELATIVE IMPORTANCE OF METALLURGICAL AND MANUFACTURING PLANTS AS A SOURCE OF SMOKE

SYNOPSIS: This chapter presents a series of comparisons which serve to indicate the amount of smoke discharged by metallurgical and manufacturing plants operating within the city of Chicago, in terms of the total smoke arising from all solid fuel fires within the city. Its purpose is to emphasize the smoke of a single service or group of similar services, by comparing it with that of all other services.

110.01 Purpose of this Study: The relative importance of various fuel consuming services as producers of smoke, and all the data developed by the Committee's investigation concerning the origin and character of smoke, have already been presented (chapter 105). It is the Committee's purpose in this chapter to emphasize the contributions to the smoke of Chicago's atmosphere which are made by metallurgical and manufacturing plants, in their relation to the contributions of all other services combined. For the present purpose, there are included under the classification "metallurgical and manufacturing plants" the following:

1. Steel plants, foundries, forges and allied processes.
2. Brick, pottery and allied processes.
3. Miscellaneous manufacturing, rendering and other processes.
4. Gas and coke plants, heretofore considered as a separate service.

All steam boiler power plants used in metallurgical and manufacturing plants are included under high pressure plants in chapter 108 and are therefore omitted from this classification.

110.02 Fuel Consumption of Metallurgical and Manufacturing Plants: The amount of smoke discharged into the atmosphere by any service is a function of the quantity of fuel consumed in that service, and the character of the smoke discharged is dependent to some extent upon the character of the fuel. With particular reference to the smoke from the furnaces of steel plants, foundries, forges and allied processes, in many of which the fires are in direct contact with the material which is being treated or refined, the character of the smoke discharged is influenced by the composition of this material. Approximately 78 per cent of the total fuel consumed by metallurgical and manufacturing plants consists of coke. As a coke consuming service, metallurgical and manufacturing plants rank first, using 98.6 per cent of the total quantity of coke consumed by all fuel consuming services in Chicago. The relative importance of this service, on the basis of the amount of fuel consumed during the year 1912 within the city of Chicago, is as follows:

	TONS	PER CENT
Consumed by metallurgical and manufacturing plants	3,931,101 . .	22.36
Consumed by all other services .	13,651,422 . .	77.64
Total	17,582,523 . .	100.00

On this basis metallurgical and manufacturing plants rank third among the fuel consuming services of Chicago.

110.03 Visible Smoke from Metallurgical and Manufacturing Plants: Visibility as a quality of smoke has reference to that property which renders smoke emissions suspended in the atmosphere apparent to the eye. It suggests the cloud effects of smoke discharges and the effects of smoke in intercepting sunlight. A standard measure of visibility is supplied by an arbitrary scale shading from white to black, with which the smoke to be observed may be compared. This is commonly referred to as the Ringelmann scale (section 105.02). As a result of the Committee's investigation, it has been determined that the relative importance of metallurgical and manufacturing plants, as producers of visible smoke in the city of Chicago, is as follows:

	PER CENT
Visible smoke produced by metallurgical and manufacturing plants . . . . :	28.78
Visible smoke produced by all other services . . .	71.22
Total	100.00

On this basis, metallurgical and manufacturing plants rank second among the smoke producing services of Chicago. It should be noted, however, that in the case of annealing or melting furnaces, in which the fire from the fuel comes directly in contact with material which is being refined or treated, such material is responsible for an appreciable proportion of the visible smoke discharged.

110.04 Solid Constituents of Smoke Discharges from Metallurgical and Manufacturing Plants: All smoke from fires sustained by solid fuels contains a certain proportion of solid constituents. This solid material may have the form of particles of mineral matter (including ash), of particles of partially consumed fuel, or of sooty particles condensed from the distillates of fuel. The smoke from the fires of steel plants, foundries and forges also carries a large burden of solid particles having their origin in materials being treated or refined.

The relative importance of metallurgical and manufacturing plants, on the basis of the total quantity of solid constituents annually discharged in the smoke of Chicago, is as follows:

	TONS	PER CENT
Solid constituents of the smoke of metallurgical and manufacturing plants . .	195,599 . .	64.26
Solid constituents of the smoke of all other services	108,792 . .	35.74
Total	304,391 . .	100.00

On this basis, metallurgical and manufacturing plants rank first among the smoke producing services in the city of Chicago, although they consume but 22 per cent of the total fuel of all services. Of the total solid constituents in the smoke of all services in Chicago, steel plants, foundries, forges and allied processes produce 63.60 per cent, brick, pottery and allied processes contribute 0.42 per cent, and miscellaneous manufacturing, rendering and other processes produce 0.24 per cent. Obviously, no close relation exists between the quantity of fuel consumed by the furnaces of steel plants, foundries and allied processes, and the amount of solid constituents in the smoke which they discharge into the atmosphere. This is due to the causes already explained.

Of the total solid materials in the smoke of all services in the city of Chicago, metallurgical and manufacturing plants are responsible for 33 per cent of the coarse cinders (those remaining on a 20-mesh sieve), 47 per cent of the fine cinders (those remaining on a 200-mesh sieve), and 70 per cent of the fuel dust (those cinders passing through a 200-mesh sieve). They are responsible also for 21 per cent of the hydrocarbons (tar), 35 per cent of the combustible solids (carbon), 76 per cent of the mineral matter and 30 per cent of the sulphur.

That 76 per cent of the total mineral matter discharged in the smoke of all services is produced by steel plants, foundries, forges and allied processes, in which coke constitutes 78 per cent of the fuel, is sufficient evidence of the fact that the heavy contribution of such furnaces to the solids in the smoke discharges is attributable, to a great extent, to the material being treated.

110.05 Gaseous Constituents of Smoke Discharges from Metallurgical and Manufacturing Plants: The gaseous constituents of smoke consist of carbon dioxid, carbon monoxid, sulphur dioxid, sulphur trioxid and air. The sulphur and carbon compounds are to be regarded as polluting gases in the atmosphere. The air accompanying the gaseous products of combustion in the smoke discharges contains more than the normal proportion of nitrogen, owing to the depletion of the oxygen content, part of which combines with the carbon and sulphur in the fuel to form the carbon and sulphur compounds mentioned. This excess of nitrogen may be regarded as effecting a dilution of the atmosphere, and it is included with the carbon and sulphur compounds as a gaseous product of combustion. The excess air discharged with these gases is not considered in making the determinations.

The total volume of the gaseous products of combustion annually discharged into the atmosphere of Chicago by metallurgical and manufacturing plants, and by all other fuel consuming services of the city, is as follows:

	CUBIC FEET	PER CENT
Gases of combustion contained in the smoke of metallurgical and manufacturing plants .	876,087,850,456 . .	21.13
Gases of combustion contained in the smoke of all other services	3,269,587,487,262 . .	78.87
Total	4,145,675,337,718 . .	100.00

Upon this basis metallurgical and manufacturing plants rank third among smoke producing services in Chicago. Steel plants, foundries, forges and allied processes are responsible for more than 98 per cent of the polluting gases contributed by this service, the remaining 2.0 per cent being contributed by brick and pottery kilns, and by furnaces used for miscellaneous manufacturing processes.

110.06 Relative Importance of Metallurgical and Manufacturing Plants as Smoke Producers on Each of the Bases Considered: The extent to which metallurgical and manufacturing plants contribute to the pollution of the atmosphere of the city of Chicago, on the bases of fuel consumed, visible smoke, solid constituents of smoke and gaseous constituents of smoke, is shown diagrammatically by fig. 33.

110.07 Conclusions to be Drawn with Reference to the Extent to which Smoke Discharges from Metallurgical and Manufacturing Plants Pollute the Atmosphere of Chicago: This study of the results of the Committee's numerous tests and analyses made in connection with the investigation of smoke discharges justifies the following conclusions with reference to the extent to which the smoke discharges from metallurgical and manufacturing plants constitute a source of atmospheric pollution:

1. Metallurgical and manufacturing plants consume 22.36 per cent of the total amount of fuel and 98.6 per cent of the coke consumed within the city limits of Chicago, ranking third as a fuel consuming service and first in the consumption of coke.

2. Metallurgical and manufacturing plants are responsible for 28.78 per cent of the total visible smoke discharged within the city limits of Chicago.

3. Metallurgical and manufacturing plants are responsible for 64.26 per cent of the total solid constituents discharged into the atmosphere in the smoke of all services within the city limits of Chicago.

4. Metallurgical and manufacturing plants are responsible for 76 per cent of the total mineral matter discharged into the atmosphere in the smoke of all services within the city limits of Chicago.

5. Metallurgical and manufacturing plants are responsible for 21.13 per cent of the total gases of combustion discharged into the atmosphere in the smoke of all services within the city limits of Chicago.

6. Steel plants, foundries, forges and allied processes are responsible for about 98 per cent of both the solid constituents of smoke and the gaseous constituents of smoke from all metallurgical and manufacturing plants within the city limits of Chicago.

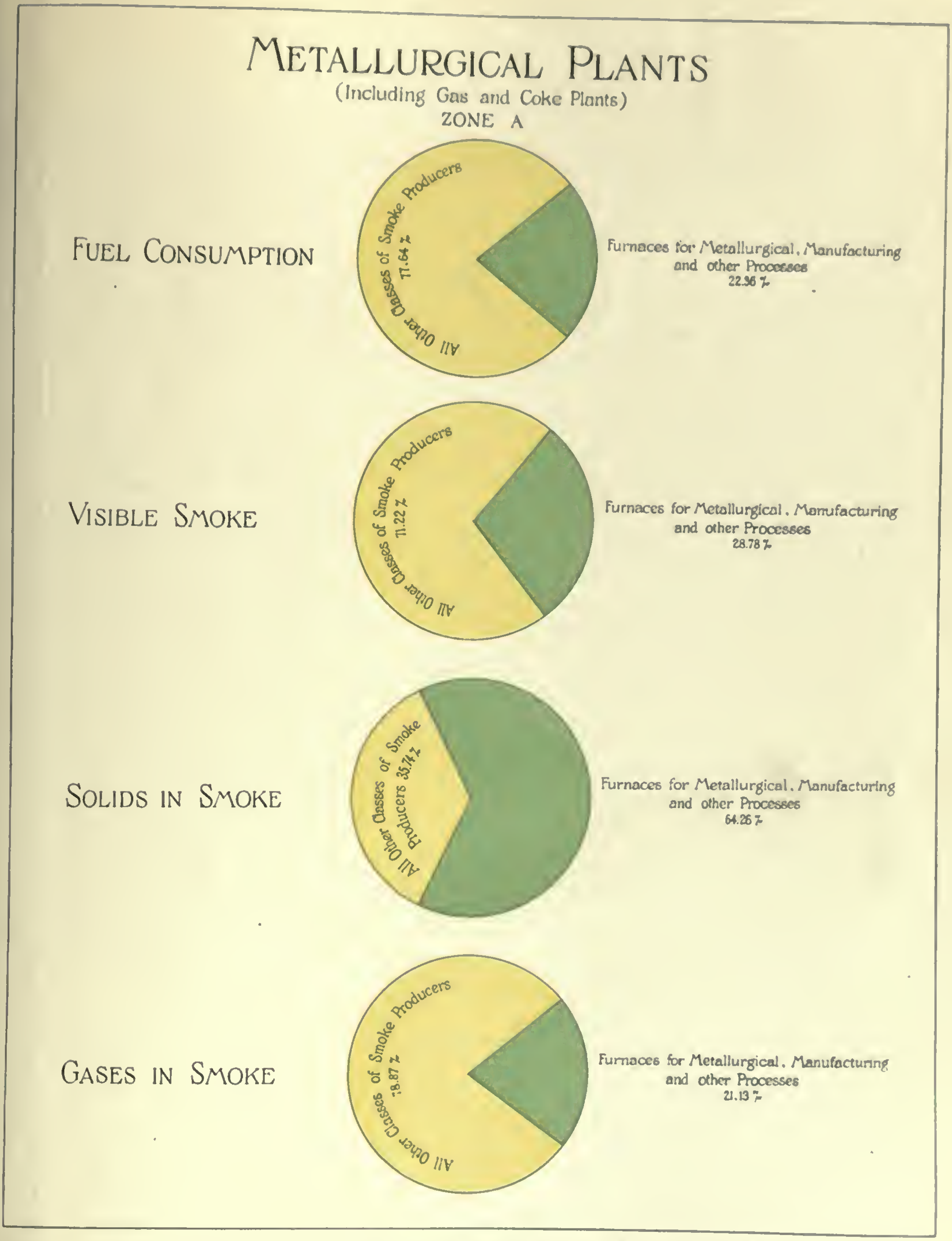

FIG. 33 RELATIVE IMPORTANCE OF PLANTS FOR METALLURGICAL, MANUFACTURING AND OTHER PROCESSES, INCLUDING GAS AND COKE PLANTS, AS A FUEL CONSUMING AND SMOKE PRODUCING SERVICE

111. SMOKE FROM OIL FUELS

SYNOPSIS: The Committee's investigations relating to fuel consumption and smoke, the results of which are presented in the preceding chapters of this report, have dealt entirely with solid fuels and with the smoke arising from their combustion. It is the purpose of this chapter to consider the extent to which oil fuels are used in the Area of Investigation and to discuss the effects of the smoke of such fuels.

111.01 The Consumption of Oil within the Area of Investigation: The Committee's studies of fuel consumption and smoke have dealt chiefly with solid fuels and with the products of their combustion. The amounts of coal and coke consumed in the furnaces of the various services have been determined with accuracy. The results of this study have already been set forth (chapter 104). A statistical study of fuel oils has not been included in the Committee's investigations since the relative importance of such oils as compared with solid fuels is not great. Oil is regarded, however, of sufficient importance as a fuel to warrant a brief review of the facts concerning its use and a study of its significance as a source of atmospheric pollution.

Illinois is one of the chief oil producing states. During the period from 1906 to 1912, inclusive, it produced a total of 196,500,000 barrels of petroleum, of 42 gallons each. Its yield in the Committee's statistical year, 1912, amounted to 28,601,308 barrels, or approximately 13 per cent of the yield of the entire country for that year. This annual production exceeds the amount produced by any other states, except Oklahoma and California.[*] While no detailed survey has been made, estimates indicate that the amount of oil delivered to points within the Area of Investigation during 1912 was as follows:[†]

	BBLS. (50 GALS.)	GALLONS
Crude or low distillate oils	3,510,840	175,542,000
Refined oil (kerosene)	231,579	11,578,950
Naphtha and gasoline	514,613	25,730,650
Total	4,257,032	212,851,600

Three barrels of crude oil in industrial furnaces or in furnaces under steam boilers may be assumed to be the equivalent of a ton of Illinois coal. Thus, 3,510,840 barrels of oil are approximately the equivalent of 1,170,000 tons of coal, or approximately 5.5 per cent of the total annual consumption of solid fuels within the Area of Investigation.

111.02 Products of Combustion of Fuel Oils: Crude or low distillate oils are chiefly used in industrial furnaces and in furnaces serving steam boilers; a small but steadily increasing amount is used in internal combustion engines. The use of such oils for industrial purposes involves the same possibilities in the development of smoke as attend the use of solid fuels. With the proper regulation of conditions affecting combustion, the smoke from oil fuels may be invisible, but the maintenance of such conditions is often attended by practical difficulties. Under conditions unfavorable to perfect combustion, the smoke from oil fires becomes dense. Results obtained from an examination of a number of typical stacks serving industrial oil fires show that, while the solid constituents of the smoke discharged by them are by no means negligible, the amount of visible smoke is not great. The facts of record have been summarized and are presented as table CVIII.

In explanation of the results presented in table CVIII, it should be noted that, of the solid constituents of smoke referred to, the tar and carbon are of fuel origin. In tests Nos. 26, 46 and 48, however, the mineral matter (ash) had its origin chiefly in the material being treated. For example, tests Nos. 26 and 48 involved brass melting furnaces, and the mineral matter detected in the smoke discharges was largely oxid of zinc. Tests Nos. 45 and 42 involved annealing furnaces in which the oil burning flame did not come in direct contact with the material under treatment,

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[*] "The Mineral Industry," Vol. XXII, 1914.

[†] The estimates of oil deliveries herein presented were made on the basis of information obtained through the assistance of Mr. L. J. Drake, Chicago. (See Archives of the Committee, Vol. D.)

and for these tests the solids emitted, including the mineral matter, were chiefly or entirely of fuel origin.

111.03 Comparison of Fuel Oil and Coal as Smoke Producers: Results of observations of smoke discharged by stacks serving special industrial furnaces fired with coal, which may be compared with the results of observations of similar furnaces fired with oil, hereinbefore presented, are set forth as table CIX.

TABLE CVIII. SMOKE DISCHARGED BY STACKS SERVING SPECIAL FURNACES FIRED WITH OIL

Test No.	Kind of Fuel	Duration Min.	Lbs. of Oil	Smoke Density Per Cent	Solid Constituents Pounds					Solid Constituents In Per Cent of Fuel Fired				
					Hydro-Carbons (Tar)	Combustible Solids (Carbon)	Mineral Matter (Ash)	Sulphur	Total	Hydro-Carbons (Tar)	Combustible Solids (Carbon)	Mineral Matter (Ash)	Sulphur	Total
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
26	Fuel Oil	130	462	14.60	0.3	7.3	24.6	0.8	33.0	0.065	1.583	5.322	0.173	7.143
45	Texas Crude	414	18,975	0	8.1	5.4	5.9	0.3	19.7	0.043	0.028	0.031	0.002	0.104
46	" "	433	4,060	0	4.4	9.5	5.3	*	19.2	1.084	2.339	1.305	*	4.728
48	" "	335	338	0	1.4	13.1	39.5	0.3	54.3	0.414	3.881	11.681	0.089	16.065
42	" "	480	600	0	0.1	0.3	0.4	*	0.8	0.016	0.050	0.067	*	0.133

* Not determined.

The furnaces referred to in table CIX are generally similar to those listed in table CVIII, and the results may be directly compared with the results of tests Nos. 45 and 42, since the constituents of the smoke discharged from the stacks for these tests are almost entirely of fuel origin. The furnaces represented in tests Nos. 31, 32, 63 and 64 consumed producer gas made from coal in a producer of the pressure type. The gas was passed directly into an annealing or reheating furnace and there burned, the products of combustion passing into a flue and thence to the stack. With the exception of test No. 49, in which anthracite was used, the visible smoke density was higher than that produced by the oil burning furnaces. The results of tests Nos. 31 and 32 disclose a relatively high percentage of tar; and while the amount of solid constituents contained in the smoke was relatively low for this class of furnace, it was considerably higher than that detected in the smoke of the oil burning furnaces of tests Nos. 45 and 42.

The results which are set forth in the preceding paragraph are entirely consistent with the view entertained by those who are familiar with the use of oil as a fuel for industrial fires. The superiority of the oil, from the standpoint of smoke abatement, when used for industrial fires, is not questioned.

The low sulphur content in the smoke from oil fires provides an additional reason for the belief that the smoke from such fires is less objectionable than that which arises from solid fuel.

As previously noted, the smoke arising from oil fires has not been included in that charged to the various services in the Committee's survey as set forth in chapter 105. The effects of smoke arising from all possible sources, however, are comprehended in the Committee's study of the atmosphere of Chicago, the results of which are hereinafter set forth (chapter 113).

111.04 Products of Combustion of Refined Oils: The oils designated as "refined" may be assumed to be kerosene, and of the 231,579 barrels consumed annually within the Area of Investigation, it is estimated that 10 per cent (about 23,000 barrels) is used in domestic stoves for cooking. The remaining amount serves for

TABLE CIX. SMOKE DISCHARGED BY STACKS SERVING SPECIAL FURNACES FIRED WITH COAL

Test No	Kind of Fuel	Duration Min.	Lbs. of Coal	Smoke Density Per Cent	Solid Constituents Pounds					Solid Constituents in Per Cent of Fuel Fired				
					Hydro-Carbons (Tar)	Combustible Solids (Carbon)	Mineral Matter (Ash)	Sulphur	Total	Hydro-Carbons (Tar)	Combustible Solids (Carbon)	Mineral Matter (Ash)	Sulphur	Total
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
41	Bituminous	400	1,333	10.45	0.9	9.9	9.4	0.8	21.0	0.068	0.744	0.707	0.060	1.579
49	Anthracite	435	2,624	0	0.7	10.3	35.6	0.6	47.2	0.027	0.392	1.356	0.023	1.798
31	Bituminous	352	11,587	16.70	42.0	19.0	8.2	*	69.2	0.363	0.164	0.071	*	0.598
32	"	324	10,800	11.30	74.2	16.2	36.0	*	126.4	0.687	0.150	0.334	*	1.171
63	"	400	8,800	7.87	5.8	82.5	42.7	2.7	133.7	0.066	0.937	0.485	0.031	1.519
64	"	395	6,860	3.87	2.9	62.2	42.0	2.7	109.8	0.043	0.907	0.612	0.040	1.602

* Not determined.

use in lamps and in lanterns and to a limited extent in special heaters of various kinds. It may be assumed that no appreciable quantity of visible smoke, soot or dust arises from the combustion of this fuel.

111.05 **Products of Combustion of Naphtha and Gasoline:** Of the naphtha and gasoline consumed within the Area of Investigation, it is estimated that fully 85 per cent of the total (approximately 437,000 barrels) is consumed in automobile service. With this amount of fuel must be included a considerable quantity of lubricating oils, the presence of which increases the smoke effects arising from the exhaust of engines. Under certain conditions automobile smoke is visible, and whether visible or not, its discharge into the atmosphere constitutes a polluting agency similar in general character, but differing much in detail, from that discharged from chimneys and stacks. The smoke from automobiles is discharged near the ground, where its presence is most objectionable to pedestrians, and being more or less surcharged with oil, it is especially offensive to those enveloped by it. Where the street traffic is most congested, the polluting effects are pronounced. In Chicago, during the morning and evening hours, the blue haze of automobile smoke is distinctly noticeable in important thoroughfares frequented by automobiles. The extent to which the smoke from automobiles is objectionable as a polluting agent in the atmosphere, depends not only upon the volume of automobile traffic but upon the state of the atmosphere, and especially upon the direction and velocity of the wind. The purpose of this reference is to record the fact that the combustion of oil fuel in automobile service constitutes a source of atmospheric pollution, and that under conditions now prevailing it is likely to increase.

111.06 **Gaseous Products of Combustion of Fuel Oils:** No tests have been conducted by the Committee to determine the amount and character of the gaseous products of the combustion of fuel oils. In general, these gaseous products are similar to those resulting from the combustion of bituminous coal and, as hereinbefore set forth (chapter 105), they do not constitute a relatively important source of atmospheric pollution.

111.07 **Conclusions with Reference to Smoke from Fuel Oils:** The facts presented by the preceding sections justify the following summary:

1. Approximately 3,511,000 barrels of fuel oil were burned in the Committee's Area of Investigation, chiefly in industrial fires, during the year 1912. This amount of oil is the equivalent of 1,170,000 tons of coal, or about 5.5 per cent of the annual consumption of solid fuel.
2. Oil fires are not necessarily smokeless but, under normal conditions of operation, the smoke arising from them is less than that from coal fires in similar service.
3. The amount of smoke arising from the consumption of fuel oil has not been quantitatively determined. The gross amount, although by no means negligible, is relatively small compared with the total smoke produced in Chicago.
4. The kerosene consumed within the Area of Investigation (231,579 barrels annually) is used chiefly for lighting, and practically no visible smoke results.
5. The gasoline and naphtha consumed within the Area of Investigation (514,613 barrels annually) is used chiefly for automobile engines. The smoke from this service is sufficient to constitute a source of atmospheric pollution.

112. ALLIES OF SMOKE IN ATMOSPHERIC POLLUTION

SYNOPSIS: Not all that pollutes the air is of fuel origin. Some of the primary sources of atmospheric dust are bare ground areas, including unimproved streets and alleys, fuel and building materials stored and in transit, building operations, street construction and repairs, the abrasion of streets and sidewalks under traffic, and back yard and roof accumulations and activities. Secondary sources appear in conditions which permit dust, once settled from the atmosphere, to be redistributed by the wind. The results of the Committee's investigations presented in this chapter show that not more than two-thirds of all the dust and dirt in the atmosphere of Chicago is of fuel origin.

112.01 Sources of Atmospheric Pollution other than Smoke: Thus far in the discussion of atmospheric pollution attention has been given only to smoke, but not all that pollutes the atmosphere is of fuel origin. Dust from many sources mingles with that of smoke to make up the sum total of the dust content of Chicago's atmosphere.

FIG. 34. BARE GROUND AREAS. View August 21, 1914. Owing to the sandy nature of the soil in Chicago, many lots and other areas are practically bare. The surface dries out and the resulting dust is caught up by the wind.

If all the fires of Chicago were stopped, dust and dirt in its atmosphere would remain. On days when the atmosphere is dry and the wind velocity high, the air is filled with dust particles. This manifestation is not confined to the streets of the city, for dust finds its way into buildings and displays its polluting effects wherever it falls.

Atmospheric pollution cannot be reduced to a minimum through attention to smoke abatement alone. In order to accomplish its reduction, attention must be given to all of those processes and activities of the city which give rise to dust or which deal with the collection and disposal of city dirt and waste.

The amount of city dust is a function of efficiency in city sanitation. It depends upon standards of cleanliness observed in the maintenance of streets and alleys and upon methods employed in cleaning them. It is important, therefore, in considering means to be employed in reducing the atmospheric pollution of the city, to give due attention to all sources from which city dust arises.

PRIMARY SOURCES OF ATMOSPHERIC DUST

112.02 Bare Ground Areas: Bare ground areas, unprotected by the improvements of the city or by vegetable growth, constitute a prolific source of atmospheric dust, or of dust which, when caught up by air currents, remains suspended in the atmosphere for considerable periods. When subjected to the traffic of vehicles, the surface of such areas becomes pulverized and yields large quantities of materials sufficiently light to be borne into the atmosphere. The extent of such areas within the limits of Chicago is in the aggregate great. Examples of areas of this character are illustrated by figs. 34 and 35.

The streets and alleys of Chicago make up a system of thoroughfares not all of which are improved. The facts as they existed at the close of the year 1912, are as follows:

	MILES
Improved streets in Chicago, including Morgan Park	1,730
Improved alleys in Chicago, including Morgan Park	160
Total	1,890
Unimproved streets in Chicago, including Morgan Park	1,276
Unimproved alleys in Chicago, including Morgan Park	1,357
Total	2,633
	SQ. MILES
Area between property lines embraced by improved streets and alleys, approximately	21
Area between property lines embraced by unimproved streets and alleys, approximately	20
Total area, approximately	41

FIG. 35. BARE GROUND AREAS. The view shows a team road, September 4, 1914. Bare ground when subjected to team traffic readily pulverizes to a fine dust which is easily borne on the air currents.

The record shows that approximately one-fifth of the total area of the city of Chicago is occupied by streets and alleys. More than half of the linear measure of these thoroughfares is as yet unimproved, and the area of the unimproved streets and alleys between property lines is equal to 10 per cent of the total area of the city. These areas are not all, nor largely, in the outlying portions of the city; the unimproved alley especially is present in many localities. These unimproved streets and alleys are all subject to traffic, some of them to comparatively heavy traffic. Being unimproved, they are often neglected; animal droppings accumulate, and litter and dirt of many sorts collect. The passing traffic in wet weather intermixes the earth and debris, and in dry weather they are again pulverized. The constant repetition of this process, with the continual grinding action of the traffic over 2,600 miles of unimproved thoroughfares, prepares and liberates considerable portions of the material which constitutes the atmospheric dust of Chicago. Examples of unimproved thoroughfares are shown by figs. 36 and 37.

FIG. 36. UNIMPROVED STREET. Photograph taken August 21, 1914. Many of Chicago's streets are unimproved. Constant travel upon them keeps the surface pulverized, and dust from them is easily blown about by the wind.

Included in the area of the city's streets and alleys is the area between sidewalks and curbs. These, in many portions of the city, where streets and sidewalks are fully improved, are grass covered and, where the sod is well maintained, no great amount of dust arises.

FIG. 37. UNIMPROVED ALLEY. Photograph taken September 4, 1914. A constant stream of delivery, coal, ice and peddlers' wagons passes over the alleys of the city. Only a few of these are improved. When wet they are muddy and unsightly; when dry they are prolific sources of dust.

In other parts of the city, however, the parkways are partially or totally neglected; many are bare of grass and afford places of deposit for refuse. They too often constitute playgrounds for children denied more attractive surroundings. The winds which sweep them easily pick up the dust from their surface. The bare areas in small parks and playgrounds make contributions to the atmospheric dust of Chicago which are by no means negligible. Examples of such areas are shown by figs. 38 and 39.

112.03 Stored Materials: Piles of fuel, building and other materials stored about the city frequently become important sources of atmospheric dust. Coal yards containing thousands of tons of coal are exposed to the weather. Dust made by the breaking of coal when it is unloaded from cars, dropped into wagons from storage bins or handled by shovels or locomotive cranes, is blown into the atmosphere, and particles which are sufficiently fine are transported over the city. Examples of such storage piles are shown by figs. 40 and 41.

The handling and storage of crushed stone, gravel, sand, lime, cement, brick and tile, yield up their quota to the dust of the atmosphere. Excavated materials from foundations and basements are frequently piled on vacant lots. The surface dries and is blown away by the wind, the process being repeated as long as the pile remains. Such sources of atmospheric dust are illustrated by fig. 42.

112.04 Back Yards and Roofs: Back yard activities in Chicago assume many different aspects. Many yards are well kept, while many others are neglected. Some are bare, some are used for the storage of merchandise, some are covered with refuse, some shelter animals, some afford space for the activities of the home or space upon which workmen ply trades. The standards of cleanliness recognized in the maintenance of back yard operations are not always high, and

FIG. 38. BARE GROUND AREAS, A SOURCE OF DUST. Many vacant lots and small parks provided by the city afford places for children to play. Constant use abrades the surface and supplies a coating of dust to be swept away by the wind. The view shows a small Chicago park.

low standards foster sources of dust. An example of such sources of dust is illustrated by fig. 43.

The growing congestion of the city tends to increase the use of its roofs. Activities which under simpler conditions may proceed in the back yard are, where lofty buildings prevail, not infrequently transferred to the roof. There are roofs in Chicago with platforms for beating carpets and with laundry equipments. Others furnish storage room for supplies and discarded materials of many sorts. Some are used for housing animals, some provide recreation space for employes of buildings, and others supply places in which mechanics having work within the buildings may set up their benches. Any unusual event affecting activities within the building is likely to be reflected by conditions on the roof. Not all of these activities of the roof are dustless. An illustration of such a source of dust is presented as fig. 44.

FIG. 39. BARE GROUND AREAS, A SOURCE OF DUST. A school playground, September 1, 1914. Many of the school yards of Chicago are covered with cinders. Children at play grind the cinders under foot and the fine particles are taken up by the wind.

112.05 Building Operations: Building operations involve the handling and the temporary storage, at the level of the street and at higher levels, of many materials which give rise to dust. The delivery of brick, tile, lime, cement and sand, and their handling throughout the structure of the building under construction, permit dust which arises from them to be widely distributed. Examples of such sources of dust are shown by figs. 45, 46 and 47.

FIG. 40. STORED MATERIALS, A SOURCE OF DUST. View showing the handling of coal, August 21, 1914. In the handling of coal in the various coal yards of the city, dust is liberated, particularly when the handling is done with a locomotive crane from piles of dry coal.

Such building operations are very likely to be preceded by those of wrecking old structures which are to give way to the new, and many of the processes of wrecking buildings are dust producing, as is shown by fig. 48.

The extent of these enterprises in Chicago is but imperfectly suggested by the record of licenses issued and permits granted. It is nevertheless of interest to note that during the Committee's statistical year, 1912, 372 buildings were wrecked, 672 were moved, 14,000 were repaired and 11,325 new buildings were started. In all of these activities incident to the

FIG. 41. STORED MATERIALS, A SOURCE OF DUST. View showing the handling of coal by hand. Many cars of coal are unloaded daily on the team tracks and in the coal yards of Chicago. The dust arising from such operations is caught up by the wind and distributed over wide areas.

life of a great and growing city, large quantities of dust are necessarily developed.

112.06 Street Construction and Repairs: Street construction and repairs give rise to dust chiefly through the handling of materials, and through interferences with traffic occasioned by the presence of materials temporarily stacked in streets. Such construction is necessary in work of renewing or repairing underground pipes or conduits belonging to the city or to public service corporations, as well as in work of repairing street foundations or surfaces. The difficulties of performing such work rapidly without interruption to traffic are such as ordinarily prevent very careful attention to the dust arising from it. The suppression of dust from such sources is a problem affecting many interests, and it is evident that effective steps to accomplish it may lead to increased costs of performing the work involved. Examples of such sources of dust are shown by figs. 49 and 50.

FIG. 42. EXCAVATED MATERIALS, A SOURCE OF DUST. During the construction of buildings, piles of excavated materials are frequently placed on adjoining vacant lots. The surface of such piles quickly dries out, affording the wind an opportunity to take up the resulting dust.

The extent to which activities of this sort occurred in Chicago during the Committee's statistical year, 1912, may be judged from the following:

New street construction reported by Board of Local Improvements covering asphalt, brick, concrete, macadam, block, etc. . . .	99 miles
Repairs to improved streets of all classes by the city . . .	1,168,630 sq. yds.
Restoration of pavements of all classes on improved streets by public service companies and others	756,488 sq. yds.
New sidewalks, by Board of Local Improvements . . .	242 miles
Street railroad track, new extensions, temporary construction and reconstruction	115 miles

These facts show the extent to which the surfaces of city streets are subject to change. They suggest the extent to which old materials are dug out and handled in the process of removal, and the extent to which new materials are temporarily stacked in the streets and on sidewalks. Stacks of such materials are exposed to sunshine and wind. They are handled under conditions which give rise to dust particles, some of which are borne even into the upper atmosphere of the city. Fig. 51 illustrates a case in which such materials are temporarily piled in the streets.

FIG. 43. NEGLECTED BACK YARDS, A SOURCE OF DUST. Photograph taken September 1, 1914. This view shows conditions after a rain. Within a short period the surface dries out, and the children and fowls soon pulverize the surface into dust which is readily taken up by the air currents.

112.07 Materials in Transit on Streets: The transportation of merchandise, especially of bulk material, such as coal, ashes, brick and sand, over city streets often results in the scattering of materials on the surface of streets. A loose end-board or an open seam in the bottom of a wagon may permit sand or ashes to sift through with every jolt of the wagon. The careless loading or the overloading of a truck or wagon permits coal, brick or other material to slip off as the vehicle proceeds. Whatever material finds its way to the surface of an improved street sooner or later comes under the grinding action of wheels. Such particles as are not recovered in the periodical cleaning of streets or washed away by rain ultimately find their way into the atmosphere.

Processes incidental to the shipment of materials, especially if carelessly conducted, give rise to litter in many forms. The teaming yards of railroads, in which all kinds of merchandise are loaded and unloaded, present one aspect of this difficult problem. Examples of such sources of dust in Chicago are illustrated by figs. 52, 53 and 54.

FIG. 44. ROOF ACTIVITIES, A SOURCE OF DUST. On many of the roofs in Chicago, particularly in the hotel and café districts, household activities are carried on extensively. The beating of rugs and carpets and the cleaning and maintenance of furniture and draperies add considerably to the total of atmospheric dust in Chicago.

112.08 Abrasion of Streets and Sidewalks: Attention has already been called to the unimproved streets and alleys of Chicago as sources of atmospheric dust. The fact should not be overlooked that the improved streets and alleys, while less productive of dust, are nevertheless subject to wear, and wear implies the production of dust. The traffic on many portions of Chicago's 1,890 miles of improved streets and alleys is heavy. During the period from May 1, 1912, to April 30, 1913, vehicles were licensed by the city as follows:

Automobiles and motorcycles .	24,397
Horse drawn wagons or carriages	55,502
Total	79,899

FIG. 45. BUILDING OPERATIONS, A SOURCE OF DUST. The handling of crushed stone, sand, cement and other building materials liberates large quantities of dust which are taken up in the air and distributed by the wind.

FIG. 46. BUILDING OPERATIONS, A SOURCE OF DUST. Photograph taken September 2, 1914. In the handling of hollow tile, brick and plastering materials considerable dust is permitted to escape into the atmosphere.

TABLE CX. EXTENT OF TRAFFIC PASSING A GIVEN POINT IN CHICAGO DURING A PERIOD OF ONE HOUR, OCTOBER, 1913

Location	Horse-drawn Vehicles	Automobiles	Motor-cycles	Bicycles	Pushcarts	Equestrians	Total
1	2	3	4	5	6	7	8
Michigan Blvd., near Jackson Blvd.	64	1,684	23	7	0	0	1,778
Rush Street Bridge	437	1,028	15	4	0	12	1,496
Jackson Blvd., near Franklin St.	134	703	31	11	1	0	880
Polk St., near Dearborn St.	453	66	0	0	3	2	524
Lake St., near Clark St.	428	51	6	1	4	2	492
Fifth Ave., near Harrison St.	419	41	0	0	2	4	466
State St., near Madison St.	352	193	2	0	2	4	553
Madison St., near Wabash Ave.	131	319	1	1	3	7	462
South Water St., near Clark St.	308	84	1	0	0	5	398
La Salle St., near Monroe St.	291	235	4	0	3	3	536
Washington St., near Wabash Ave.	67	286	5	0	0	0	358
State St., near Van Buren St.	277	80	0	1	0	4	362
Clark St., near Adams St.	245	123	1	1	1	0	371
Washington St., near State St.	100	256	0	0	0	2	358
Madison St., near Fifth Ave.	251	84	1	0	1	0	337
Dearborn St., near Monroe St.	218	89	1	1	2	3	314
Dearborn St., near Randolph St.	163	69	0	0	4	4	240
Fifth Ave., near Randolph St.	187	39	0	0	2	3	231
La Salle St., near Madison St.	182	137	2	0	1	0	322
Randolph St., near State St.	166	114	2	0	0	0	282

This is an average of 43 vehicles per mile of improved streets and alleys.

To establish facts with reference to the density of vehicle movements under normal daylight conditions in the more congested parts of the city, observations were made by the Committee in October, 1913, covering 20 different localities. During the 75 hours which were embraced by these observations, a single set of observers counted 16,855 horse drawn vehicles, 24,728 automobiles, 461 motorcycles, 145 bicycles, 127 pushcarts and 200 equestrians. The several points at which observations were made and a summary of observed results during one hour for each of the 20 localities specified, are set forth in table CX. It was sought to have the record hour represent the hour of maximum traffic for the day.

The purpose of this exhibit is to direct attention to the extent of activities which must result in the wear of street surfaces and of tires, and consequently in the production of dust. To the abrasive action of the street must be added that of the sidewalk. The movement of multitudes of people over hundreds of miles of walks adds its quota to the sum total of the dust of the city.

FIG. 47. BUILDING OPERATIONS, A SOURCE OF DUST. The handling of cement scatters fine dust, and the removal of crushed stone and sand from piles in the street leaves the latter but "shovel clean." The residue becomes dry and is blown away by the wind.

112.09 Manufacturing Operations: Manufacturing processes give rise to dust. Metallurgical furnaces and the furnaces of cement mills are, in many cases, prolific sources of atmospheric dust. Grinding processes incident to the operations of flour mills produce vegetable dust, and factories, foundries and machine shops produce large quantities of mineral dust. Tumbling barrels employed in cleaning castings, and sanders and other machines in woodworking establishments, liberate large quantities of dust, some of which finds lodgment near its source, while considerable portions are borne long distances in the atmosphere.

112.10 Waste Materials: Waste of many sorts must be

FIG. 48. BUILDING OPERATIONS, A SOURCE OF DUST. During the construction of large buildings or in the wrecking of old ones, the refuse is frequently handled by chutes. This method provides excellent opportunity for the wind to blow away large quantities of dust.

FIG. 49. STREET CONSTRUCTION, A SOURCE OF DUST. Street scene, September 1, 1914. Nearly 100 miles of streets are improved each year in Chicago. The handling of materials liberates large quantities of dust, which are borne by the wind over long distances.

handled and in some way be disposed of. Various means are employed in Chicago for the accomplishment of this purpose, many of which are efficient and cleanly. Refuse disposal stations on the river permit wagons to dump into hoppers and provide for the discharge of hoppers into dump barges which, when loaded, are towed to dumping grounds and discharged. Large quantities of refuse are discharged into cars on the underground tracks of the Chicago Tunnel Company and conveyed to points of disposal. There are, however, processes appearing in the life of the village which still persist in the city of Chicago. One of these is the burning of waste materials in outdoor fires. Bonfires are by no means rare even in the parks. An example of such sources of pollution is illustrated by fig. 55.

During the months of June and July, 1914, fires on the breakwaters near the city were of frequent occurrence. In the month of July there were not less than eleven days during which large piles of timber refuse were destroyed by fire on the breakwater off Grant Park. On many of these days the wind was from the east and the smoke was blown directly in upon the loop district of the city.

Numerous dump piles, distributed throughout the city, give rise to frequent fires and otherwise contribute to the city's atmospheric dust. An example of such dump piles is shown by fig. 56.

112.11 The Significance of the Record: No attempt has been made in the preceding sections to present a complete enumeration of all the primary sources of atmospheric dust. The purpose has been to call attention to the more prolific and more common sources. Even a casual survey of the activities of Chicago shows a surprising frequency of processes from which dust arises. It is clear that a city which aims to minimize the pollution of its atmosphere must seek to eliminate every unnecessary source of dust.

It must recognize the necessity of extending supervision over various activities which give rise

FIG. 50. STREET CONSTRUCTION, A SOURCE OF DUST. Material is frequently piled in the street where passing vehicles grind it to powder, which is quickly taken up and borne away by the wind.

to dust and atmospheric pollution and it must take steps to improve the methods employed in cleaning streets and thoroughfares.

FIG. 51. STREET CONSTRUCTION, A SOURCE OF DUST. More than a million square yards of street repairs are made annually in Chicago. In this view a six-foot brick sewer is being laid, after which the street may long remain in the disturbed condition shown. During construction, dust is distributed about the neighborhood from the handling of cement, brick and sand. Photograph taken August 21, 1914.

SECONDARY SOURCES OF ATMOSPHERIC DUST

112.12 The Persistence of Dust of Whatever Origin: It is apparent from the facts presented in the preceding sections that atmospheric dust and dirt have their origin in many sources. It is hereinafter shown (section 112.14) that the dust and dirt of smoke account for approximately two-thirds of all the atmospheric dust. The remaining one-third is of non-fuel origin.

Whatever may be the sources of atmospheric pollution, the dust persists until it is gathered up and finally disposed of, or until it is borne by the wind to points remote from the city. A descending movement of dust appears to be nearly continuous over the city, though the rate of movement is greatly affected by local conditions. One who has occasion to inspect the sidewalks and other horizontal surfaces of the city in the early morning may readily see the dust which has fallen during the night. If the wind movement has been light, the collected dust will constitute a representative sample of the dust shower in that particular locality during the interval of quiet. But the descent of solids from the atmosphere occurs during the day as well as during the night. If the weather is dry these solids appear as dust to be swept up or blown away; if the weather is wet, they mix with the water of roofs, streets and sidewalks and give color and consistency to the watery mixture under foot and wheel. Heavy rains tend to wash away the dirt. Between rains only a portion of the falling dust is intercepted by the cleaning process of the city. The remainder, when dry, may be caught up by the air currents and borne away again.

FIG. 52. MATERIALS IN TRANSIT, A SOURCE OF DUST. From cars set on team tracks, merchandise of many kinds is handled. The bare earth is stirred up by team traffic and the litter from materials handled accumulates.

The tendency of dust once freed from its sources is to persist

FIG. 53. MATERIALS IN TRANSIT, A SOURCE OF DUST. The material on the ground along the side of the car shown is, in this case, excelsior. Being no longer needed it has been thrown out to be broken up by wheels and by the trampling of horses and finally to be taken up and distributed over wide areas by the wind.

until disposed of by some effective cleaning process.

112.13 The Elimination of Atmospheric Dust a Function of Efficiency in Municipal Housekeeping: It is a principle in good housekeeping that dirt must be found, collected and disposed of. If, in the administration of the city of Chicago, this principle were always recognized and applied, if search were made for accumulations of dirt, if accumulations, when found, were collected and disposed of, the pollution of the city's atmosphere would be materially reduced. This statement does not refer to original sources of dirt, which have already been discussed, but to the incidental accumulations of dust which have drifted into sheltered places or have been dropped or abandoned as a result of careless or disorderly methods in handling merchandise or personal effects. The streets and alleys of Chicago contain numerous accumulations of waste materials which, by the standards of good municipal housekeeping, should be collected and removed. Figs. 57 and 58 present illustrations of such accumulations.

One does not need to go far in the inspection of the roofs of buildings to find accumulations of materials which have been precipitated from the air, a large proportion of which is ready again to take flight whenever atmospheric conditions favor such a course. Besides the dirt and dust which collect on the roofs of buildings, the natural wear and disintegration of the materials used in roofing processes are sources of atmospheric dust. An example of accumulations of dirt and dust on roofs is shown by fig. 59.

A few illustrations, which are in no sense exceptional, will serve to suggest the significance of the secondary sources of atmospheric pollution to which attention is called.

Chicago's standards in municipal housekeeping are reflected in the methods employed in the public service and by individuals in the cleaning of streets and sidewalks. Dry street cleaning is apparently everywhere permitted, and in most

FIG. 54. MATERIALS IN TRANSIT, A SOURCE OF DUST. Carload of live poultry in a Chicago railroad yard. Many cars of live poultry come into the city each day. The feathers shown in the foreground are suggestive of the opportunities they afford for the distribution of dirt.

portions of the city it is generally practiced. Dry sidewalks are swept to dry street gutters. The dry sweepings are compacted into dry heaps at intervals in dry gutters, and these dry heaps are later shoveled into wagons. This practice is illustrated by fig. 60.

Every stage of this process is productive of clouds of dust and every stage is imperfect as a cleaning process. The dry sidewalks cannot be swept clean, the dry gutters cannot be swept clean and the heaps of sweepings cannot be entirely removed by the use of a shovel. Fig. 61 illustrates a typical method of cleaning streets.

FIG. 55. BURNING OF WASTE MATERIALS, A SOURCE OF DUST. Waste materials of all kinds are extensively burned throughout the city either in bonfires, as shown in this view, or in portable furnaces. The process results not only in smoke but in considerable quantities of ashes, which find their way into the atmosphere.

This procedure of cleaning streets, so common in Chicago, is in striking contrast to that employed in many other large cities. In Paris, for example, the importance of wet cleaning is recognized, and over large areas of the city special curb hydrants have been established at the high points of all street grades. Water is discharged from these curb hydrants directly into the gutter at the gutter level. A piece of burlap on one side of the stream of water, which flows with little force from the hydrants, determines which slope of the grade the water is to descend. The supply of water is abundant. Dirt accumulations in the gutter are borne away by the water to catch-basins and sewers. A street cleaner, beginning at the foot of the grade with a broad scraper opposed to the descending current in the gutter, diverts the water out into the street, and this stream is met by the scraper of a second cleaner following the first, and is thrown still farther out until the water flows over the crown of the street. A similar process from the opposite curb serves to wet the street surface thoroughly. This accomplished, the cleaners with their scrapers begin at the center of the street, moving one after the other, their scrapers so directed that all refuse is flushed from the center of the street toward the gutter. In a

FIG. 56. REFUSE DUMPS, A SOURCE OF DUST. Street sweepings are frequently used for filling in low ground. This view illustrates such a case and shows conditions favorable to the development of dust. The dump here shown is located within a block of one of Chicago's boulevards.

FIG. 57. WASTE MATERIALS, A SOURCE OF DUST. Many alleys in Chicago are used as dumping places for all sorts of refuse.

remarkably short time everything has been diverted into the gutter and the flushing stream of water has washed it away. During these processes, the water of the gutter is fouled but, with the street scraping over, it soon runs clear again. The process is repeated with sufficient frequency to keep the streets dustless.

Chicago is not without its wet cleaning. Certain of the downtown streets and sidewalks are now subject to this process, but thus far the areas affected and the degree of thoroughness attained in the execution of the work are not sufficient to make the results far-reaching in their effects.

Imperfect cleaning is not exclusively a function of methods employed in the removal of dirt. Whatever the method, the result is often only partially accomplished. For example, ashes hoisted from sub-sidewalk spaces are dumped in the gutter. A pile is thus formed. The ashes are wet and no dust arises from them. In due time they are shoveled out of the gutter into wagons and carted away, but the job is left "shovel-clean" only, the gutter is soon dry, the traffic of the street proceeds and the wind takes up what the shovel of the workman did not remove. Similarly, a main thoroughfare is re-paved. In anticipation of the work, the side streets are made places of deposit for stocks of broken stone and sand. These materials extend in long windrows on either side of an improved street. In time the work of re-paving the thoroughfare is completed and the remaining materials are drawn away, but they are not entirely removed and the side street is not thoroughly cleaned. For many days the pedestrian at the street crossing encounters evidences of the presence of sand and dirt which have not been removed.

The Committee, in its task of studying the sources of atmospheric pollution in Chicago, has found it necessary to give due attention to those sources for which the city itself is responsible.

FIG. 58. WASTE MATERIALS, A SOURCE OF DUST. Rubbish on a vacant lot, September 2, 1914. Many vacant lots in Chicago are used as dumping places for materials from wrecked buildings. The disintegration of such materials gives rise to dust which is distributed by the wind over wide areas. The old plaster shown in this view constitutes a particularly prolific source of dust.

It recognizes the fact that the problem of Chicago's municipal housekeeping is complicated by the presence of many miles of unimproved streets and alleys, by the presence of open joints in the surface of improved streets, by the newness of the city and by the fact that a community, but recently shut in from a life in the open, is confronted with the difficult problem of establishing procedures which will respond to the highest standard of municipal sanitation. But its investigations emphasize the fact that the city, in its efforts to reduce the amount of pollution entering the atmosphere of Chicago, should not be content with giving attention to smoke abatement alone. The problem is to suppress all important sources of atmospheric pollution, and while corporations and individuals must recognize their responsibility in the reduction of smoke, the city itself must seek to reduce to a minimum that portion of the total pollution which arises from sources over which it alone has control.

FIG. 59. ACCUMULATIONS OF DIRT AND DUST ON THE ROOFS OF BUILDINGS. Such accumulations consist of ashes, waste materials, sweepings and debris of many sorts. The action of the wind and air currents serves to scatter dust from such sources over wide areas.

112.14 A Quantitative Measure of the Street Dust in the Atmosphere: For the purpose of securing an estimate of the amount of atmospheric dust which is of non-fuel origin, samples of Chicago's dry sidewalk sweepings were collected in the early morning, the presumption being that the materials thus collected had settled from the atmosphere during the quiet of the night. The samples were analyzed and, while the results thus obtained do not constitute the Committee's final definition of the important question involved, they are of sufficient interest to justify their presentation. The results in full are shown by table CXI.

FIG. 60. STREET CLEANING OPERATIONS, A SOURCE OF DUST. Photograph taken September 1, 1914. Street cleaning as practiced in Chicago constitutes an objectionable source of dust.

Besides those enumerated in the table, other materials which could be identified from portions of sample No. 1, remaining on the 20-mesh screen, comprised wood, coal, stones, straw, cinders, paper, fruit, hair and fibers, oats, tobacco leaves, mica and corn.

Other materials which could be identified from portions of sample No. 2, remaining on

FIG. 61. STREET CLEANING OPERATIONS, A SOURCE OF DUST. In the common method of cleaning streets in Chicago, the refuse is swept into piles in the gutter to be collected later by teams. During the process of loading the wagons, the wind has full opportunity to blow out the finer particles. The gutter is left but "shovel clean" and these leavings in time add to the dust content of the atmosphere.

the 20-mesh screen, comprised wood, straw, gravel, feathers, hair, thread, wool fiber, paper, coal, tobacco and cinders. Other materials which could be identified from portions of sample No. 3, remaining on the 20-mesh screen, comprised pebbles and gravel, brick, porcelain, glass, straw, oats, hair and coal. Other materials which could be identified from portions of sample No. 4, remaining on the 20-mesh screen, comprised cinders, sand, stones and wood.

TABLE CXI. ANALYSIS OF SAMPLES OF DRY SIDEWALK SWEEPINGS

Sample No.	Location	Material	Per Cent of Total	Percentages							
				Ash	Organic	Nitrogen	Sulphur	Silicon Oxid	Ferric Oxid and Aluminium Oxid	Calcium Oxid	Magnesium Oxid
1	2	3	4	5	6	7	8	9	10	11	12
1	From Halsted and 16th Sts., under R. R. Elevation	Coarse cinders	7.00	14.72	85.28	1.52	0.90	8.70	2.15	1.19	0.52
		Fine cinders	34.00	57.83	42.17	0.71	0.93	41.90	5.95	3.25	1.81
		Dust	59.00	71.50	28.50	0.52	0.91	47.07	8.70	6.12	3.59
2	From Sidewalk Monroe and Market Sts.	Coarse cinders	15.62	34.00	66.00	1.09	0.71	18.90	6.60	3.07	2.78
		Fine cinders	54.95	60.02	39.98	0.77	0.75	40.45	10.50	3.50	1.19
		Dust	30.43	71.10	28.90	0.45	0.64	44.60	13.55	5.89	1.59
3	From Halsted and 16th Sts., west of R. R.	Coarse cinders	22.83	96.55	3.45	0.25	0.20	81.60	3.07	4.23	3.76
		Fine cinders	54.54	65.80	34.20	0.67	0.52	50.60	6.05	3.98	1.23
		Dust	22.63	74.69	25.31	0.52	0.63	54.00	8.42	5.73	2.96
4	From 26th St. over Illinois Central R. R.	Coarse cinders	50.90	25.73	74.27	Tar 0.29	1.5	20.30	2.5	1.33	
		Fine cinders	46.20	51.77	48.23	0.81	1.6	38.81	6.0	4 75	
		Dust	2.90	56.15	43.75	2 23	1.7	40.49	8.2	5.52	

Supplementing the collections described, samples of sidewalk sweepings were collected from the west side of Michigan Avenue, between Washington and Randolph streets, on three different mornings in December, 1913. In each case the collection was made after a dry, quiet night, and was taken from the outer half of the sidewalk. The three samples thus collected were combined, and a microscopical and chemical analysis was made of the combined sample. The results were as follows:

	PER CENT
Volatile and combustible matter	39.3
Non-combustible matter	60.7
Total	100.0

The analyses showed the presence of the following:

	PER CENT
Iron oxide, calculated to Fe_2O_3	4.0
Alumina (Al_2O_3)	8.3
Lime (CaO)	7.1
Magnesia (MgO)	2.9
Silica (SiO_2)	7.8
Nitrogen (N)	3.1
Sulphuric acid (SO_3)	3.8

These results, combined with those of a microscopical examination of the material, justify the following conclusions concerning its composition:

	PER CENT
Manure and organic debris	35.0
Ashes and cinders (matter of fuel origin)	45.0
Mineral debris not of fuel origin	15.0
Moisture and undetermined volatile matter	5.0
Total	100.0

Placing a liberal interpretation upon all results obtained from sweepings, it may be said that approximately one-third of the material collected was fuel ash, one-third was organic matter, with which is included the combustible fuel dust, and one-third was silicious and metallic. It is, perhaps, safe to say that from one-half to two-thirds of the material collected was of fuel origin.

A conclusion to the effect that two-thirds of the atmospheric dust is of fuel origin does not imply that this amount represents material which directly descends from the smoke clouds above the city. It has been shown that dust of fuel origin arises from secondary sources, such as imperfectly cleaned streets and sidewalks, as well as from the chimneys of buildings. It is conceivable that, if all discharges of smoke from chimneys were to cease for a period of many days, dust of fuel origin would still be found in the atmosphere. An analysis does not show how much atmospheric dust is due directly to smoke and how much is due to the persistence of more remote sources of dust.

CONCLUSIONS

112.15 **The Importance of Allies of Smoke in Atmospheric Pollution:** The facts already presented may be summarized as follows:

1. Streets and alleys represent approximately 20 per cent of the entire area of the city; approximately one-half of the thoroughfares are unimproved.

2. Atmospheric dust is not entirely of fuel origin; much of it — probably one-third or more of the total — arises from street traffic and from other activities of the city.

3. The amount of city dust which enters as a polluting agency into the atmosphere is a function of efficiency in city sanitation; it depends upon the standards of cleanliness observed in the maintenance of streets and alleys, and upon methods employed in cleaning.

4. Atmospheric pollution cannot be reduced to a minimum through attention to smoke abatement alone; in order to accomplish its reduction to a minimum, attention must be given to all of those processes and activities of the city which give rise to dust, or which deal with the collection and disposal of city dirt.

113. ATMOSPHERIC POLLUTION AS DISCLOSED BY A STUDY OF THE ATMOSPHERE

SYNOPSIS: The effects produced by polluting agencies in the atmosphere, whatever their origin, depend somewhat upon weather conditions. The Committee's study of the atmosphere of Chicago has, therefore, involved a comparison of meteorological phenomena in Chicago with those of other cities, and a study of such phenomena in their relation to atmospheric pollution. It has also involved the sampling of air at numerous points throughout the Area of Investigation and an analytical examination of the samples to detect and evaluate the significance of all constituents of the atmosphere, both gaseous and solid. The results of these studies and the conclusions to be drawn from them are presented in this chapter.

113.01 **Purpose of this Study:** It has been the Committee's purpose in the preceding chapters of this report to present a record of essential facts bearing upon the progress which has been made in smoke abatement throughout the world, to define the territory embraced by the Committee's investigation, to record with accuracy the amount and character of the fuel consumed within this territory, to present the results of an investigation setting forth the extent to which each of the several classes of fuel consuming services contributes to the production of smoke, and to disclose those peculiarities of each service which have a bearing upon the problem of smoke abatement. The studies previously reported, therefore, have dealt largely with the sources of smoke and with the means by which it may be abated. The present chapter deals with the more general aspects of atmospheric pollution, smoke being recognized as one of many agencies contributing thereto. It seeks to answer the question as to how much of all that is objectionable in the atmosphere is of fuel origin. It deals with the atmosphere itself and sets forth the results of an elaborate investigation of its constituents as revealed by the following studies:

1. A study of the meteorological conditions in Chicago and other cities and of the relation between meteorological conditions and atmospheric pollution.
2. A study of the atmosphere of cities as disclosed by a review of scientific literature bearing upon the subject.
3. An examination of the atmosphere of Chicago by means of an extensive series of tests involving filtration and chemical analyses of representative samples of air and also of samples of rain and snow collected at various points throughout the Area of Investigation.

A STUDY OF METEOROLOGICAL CONDITIONS IN THEIR RELATION TO ATMOSPHERIC POLLUTION

113.02 **The Influence of Meteorological Conditions upon Atmospheric Pollution:** The effects of atmospheric pollution due to smoke are intensified or diminished as a result of meteorological conditions. Scientific methods for measuring the absolute value of these effects are not available. The results are, therefore, relative.

The Committee has made an elaborate statistical study of the weather conditions in various cities in the United States and Europe, the results of which are shown by figs. 62 to 66, inclusive.

All information for this study has been obtained from official or other reliable sources. The record covers conditions prevailing during the seven-year period from 1906 to 1912, inclusive, in 39 American cities and 13 European cities. The facts thus made available have been studied, interpreted and very materially supplemented with data from other sources by Henry J. Cox, Professor of Meteorology, United States Weather Bureau, Chicago, from whose report the greater parts of the analyses presented have been summarized.*

It should be recognized that in a detailed study of meteorological data the facts presented are significant only as mean or average values. Due consideration should also be given to the methods

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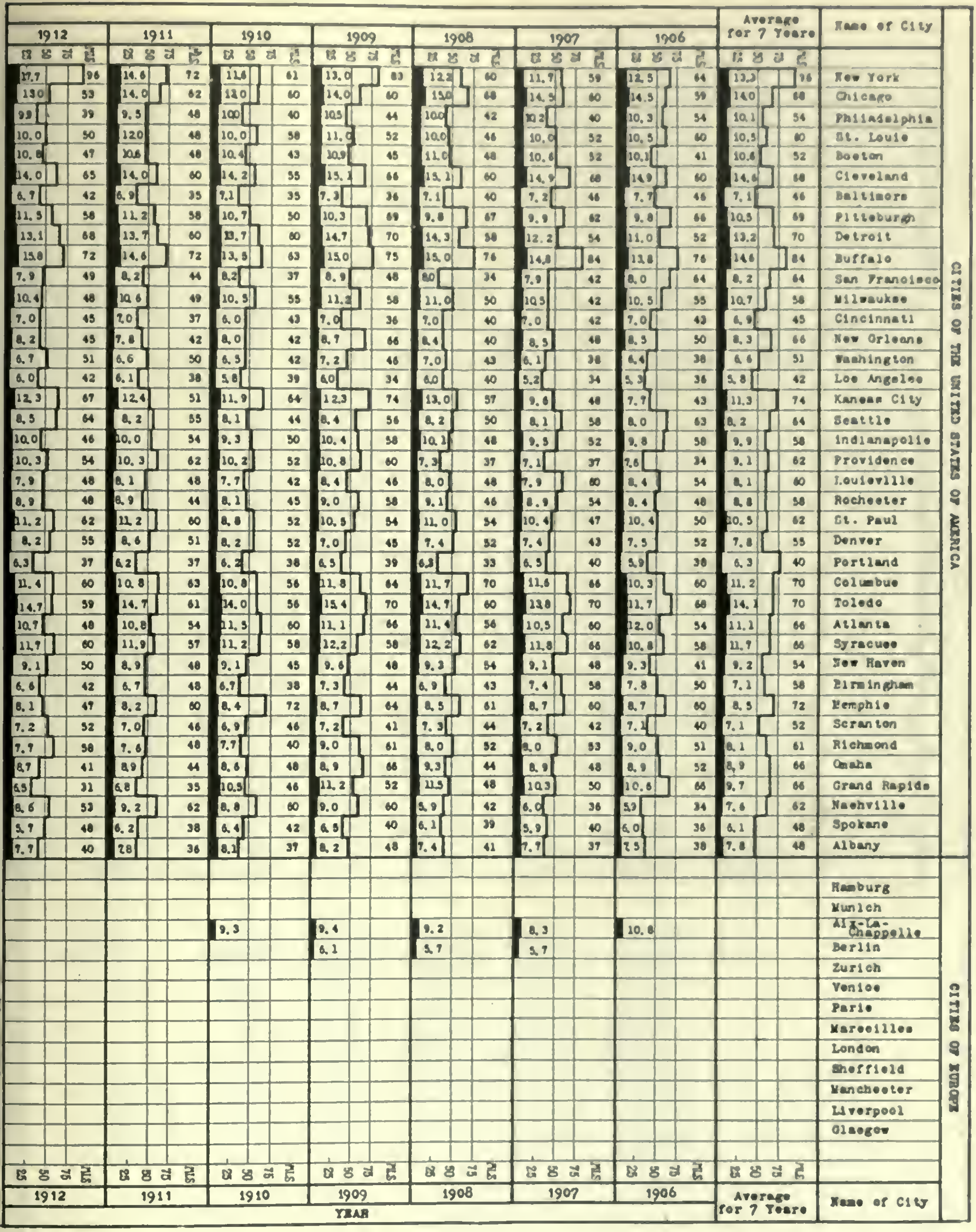
* The detailed report of Professor Cox is preserved in the Archives of the Committee, Vol. A 1.

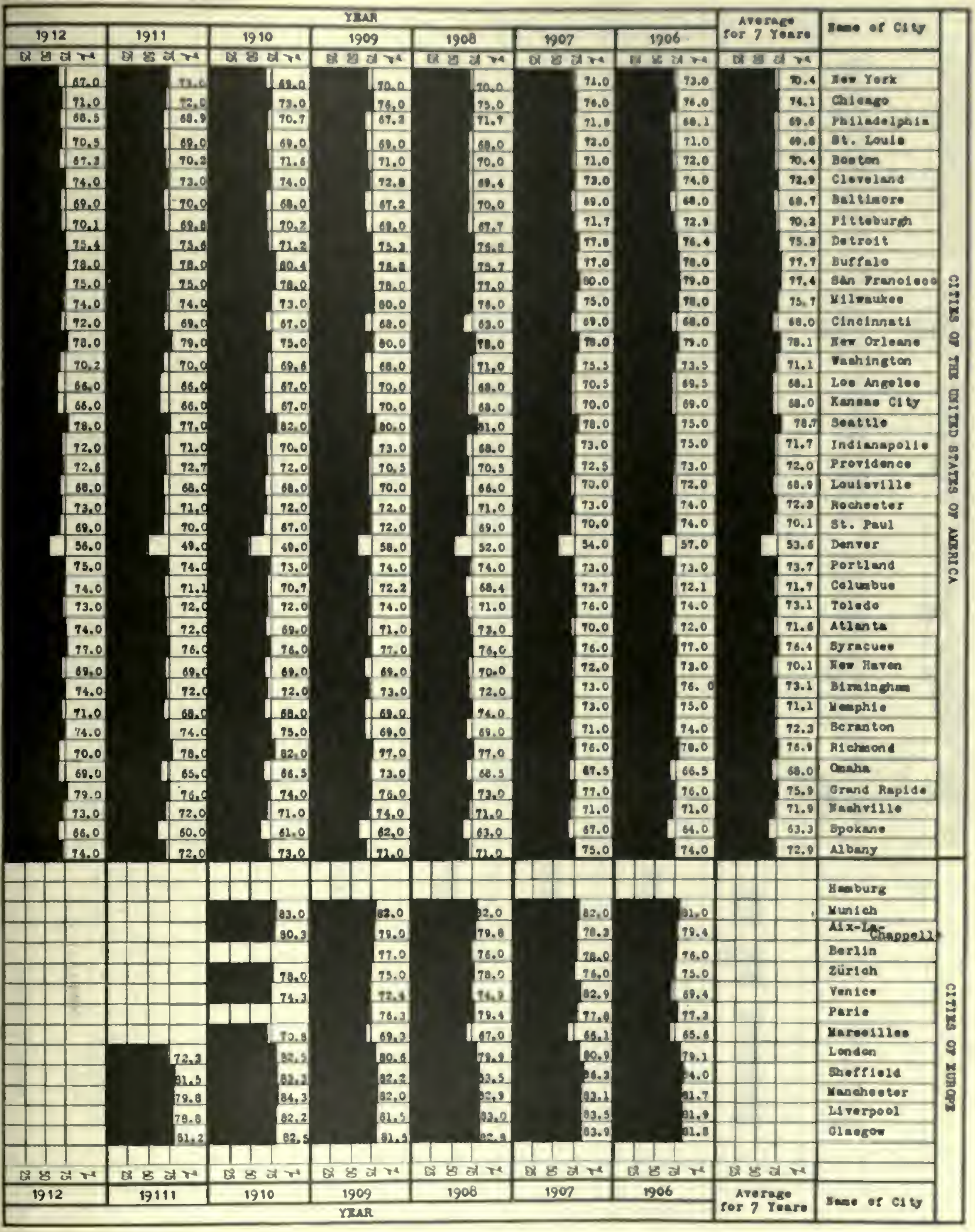


Name of City	1912		1911		1910		1909		1908		1907		1906		Average for 7 Years	
New York	17.7	96	14.6	72	11.6	61	13.0	83	12.2	60	11.7	59	12.5	64	13.3	96
Chicago	13.0	53	14.0	62	12.0	60	14.0	60	15.0	68	14.5	60	14.5	59	14.0	68
Philadelphia	9.9	39	9.5	48	10.0	40	10.5	44	10.0	42	10.2	40	10.3	54	10.1	54
St. Louis	10.0	50	12.0	48	10.0	58	11.0	52	10.0	46	10.0	52	10.5	60	10.5	60
Boston	10.8	47	10.6	48	10.4	43	10.9	45	11.0	48	10.6	52	10.1	41	10.6	52
Cleveland	14.0	65	14.0	60	14.2	55	15.1	66	15.1	60	14.9	68	14.9	60	14.6	68
Baltimore	6.7	42	6.9	35	7.1	35	7.3	36	7.1	40	7.2	46	7.7	46	7.1	46
Pittsburgh	11.5	58	11.2	58	10.7	50	10.3	69	9.8	67	9.9	62	9.8	66	10.5	69
Detroit	13.1	68	13.7	60	13.7	60	14.7	70	14.3	58	12.2	54	11.0	52	13.2	70
Buffalo	15.8	72	14.6	72	13.5	63	15.0	75	15.0	76	14.8	84	13.8	76	14.6	84
San Francisco	7.9	49	8.2	44	8.2	37	8.9	48	8.0	34	7.9	42	8.0	64	8.2	64
Milwaukee	10.4	48	10.6	49	10.5	55	11.2	58	11.0	50	10.5	42	10.5	55	10.7	58
Cincinnati	7.0	45	7.0	37	6.0	43	7.0	36	7.0	40	7.0	42	7.0	43	6.9	45
New Orleans	8.2	45	7.8	42	8.0	42	8.7	66	8.4	40	8.5	48	8.5	50	8.3	66
Washington	6.7	51	6.6	50	6.5	42	7.2	46	7.0	43	6.1	38	6.4	38	6.6	51
Los Angeles	6.0	42	6.1	38	5.8	39	6.0	34	6.0	40	5.2	34	5.3	36	5.8	42
Kansas City	12.3	67	12.4	51	11.9	64	12.3	74	13.0	57	9.6	48	7.7	43	11.3	74
Seattle	8.5	64	8.2	55	8.1	44	8.4	56	8.2	50	8.1	58	8.0	63	8.2	64
Indianapolis	10.0	46	10.0	54	9.3	50	10.4	58	10.1	48	9.5	52	9.8	58	9.9	58
Providence	10.3	54	10.3	62	10.2	52	10.8	60	7.3	37	7.1	37	7.6	34	9.1	62
Louisville	7.9	48	8.1	48	7.7	42	8.4	46	8.0	48	7.9	60	8.4	54	8.1	60
Rochester	8.9	48	8.9	44	8.1	45	9.0	58	9.1	46	8.9	54	8.4	48	8.8	58
St. Paul	11.2	62	11.2	60	8.8	52	10.5	54	11.0	54	10.4	47	10.4	50	10.5	62
Denver	8.2	55	8.6	51	8.2	52	7.0	45	7.4	52	7.4	43	7.5	52	7.8	55
Portland	6.3	37	6.2	37	6.2	38	6.5	39	6.3	33	6.5	40	5.9	38	6.3	40
Columbus	11.4	60	10.8	63	10.8	56	11.8	64	11.7	70	11.6	66	10.3	60	11.2	70
Toledo	14.7	59	14.7	61	14.0	56	15.4	70	14.7	60	13.8	70	11.7	68	14.1	70
Atlanta	10.7	48	10.8	54	11.5	60	11.1	66	11.4	56	10.5	60	12.0	54	11.1	66
Syracuse	11.7	60	11.9	57	11.2	58	12.2	58	12.2	62	11.8	66	10.8	58	11.7	66
New Haven	9.1	50	8.9	48	9.1	45	9.6	48	9.3	54	9.1	48	9.3	41	9.2	54
Birmingham	6.6	42	6.7	48	6.7	38	7.3	44	6.9	43	7.4	58	7.8	50	7.1	58
Memphis	8.1	47	8.2	60	8.4	72	8.7	64	8.5	61	8.7	60	8.7	60	8.5	72
Scranton	7.2	52	7.0	46	6.9	46	7.2	41	7.3	44	7.2	42	7.1	40	7.1	52
Richmond	7.7	58	7.6	48	7.7	40	9.0	61	8.0	52	8.0	53	9.0	51	8.1	61
Omaha	8.7	41	8.9	44	8.6	48	8.9	66	9.3	44	8.9	48	8.9	52	8.9	66
Grand Rapids	6.5	31	6.8	35	10.5	46	11.2	52	11.5	48	10.3	50	10.6	66	9.7	66
Nashville	8.6	53	9.2	62	8.8	60	9.0	60	5.9	42	6.0	36	5.9	34	7.6	62
Spokane	5.7	48	6.2	38	6.4	42	6.5	40	6.1	39	5.9	40	6.0	36	6.1	48
Albany	7.7	40	7.8	36	8.1	37	8.2	48	7.4	41	7.7	37	7.5	38	7.8	48
Hamburg																
Munich																
Aix-La-Chappelle					9.3		9.4		9.2		8.3		10.8			
Berlin							6.1		5.7		5.7					
Zurich																
Venice																
Paris																
Marseilles																
London																
Sheffield																
Manchester																
Liverpool																
Glasgow																

FIG. 62. MAXIMUM AND AVERAGE WIND VELOCITIES IN 39 AMERICAN AND 13 EUROPEAN CITIES, 1906—1912

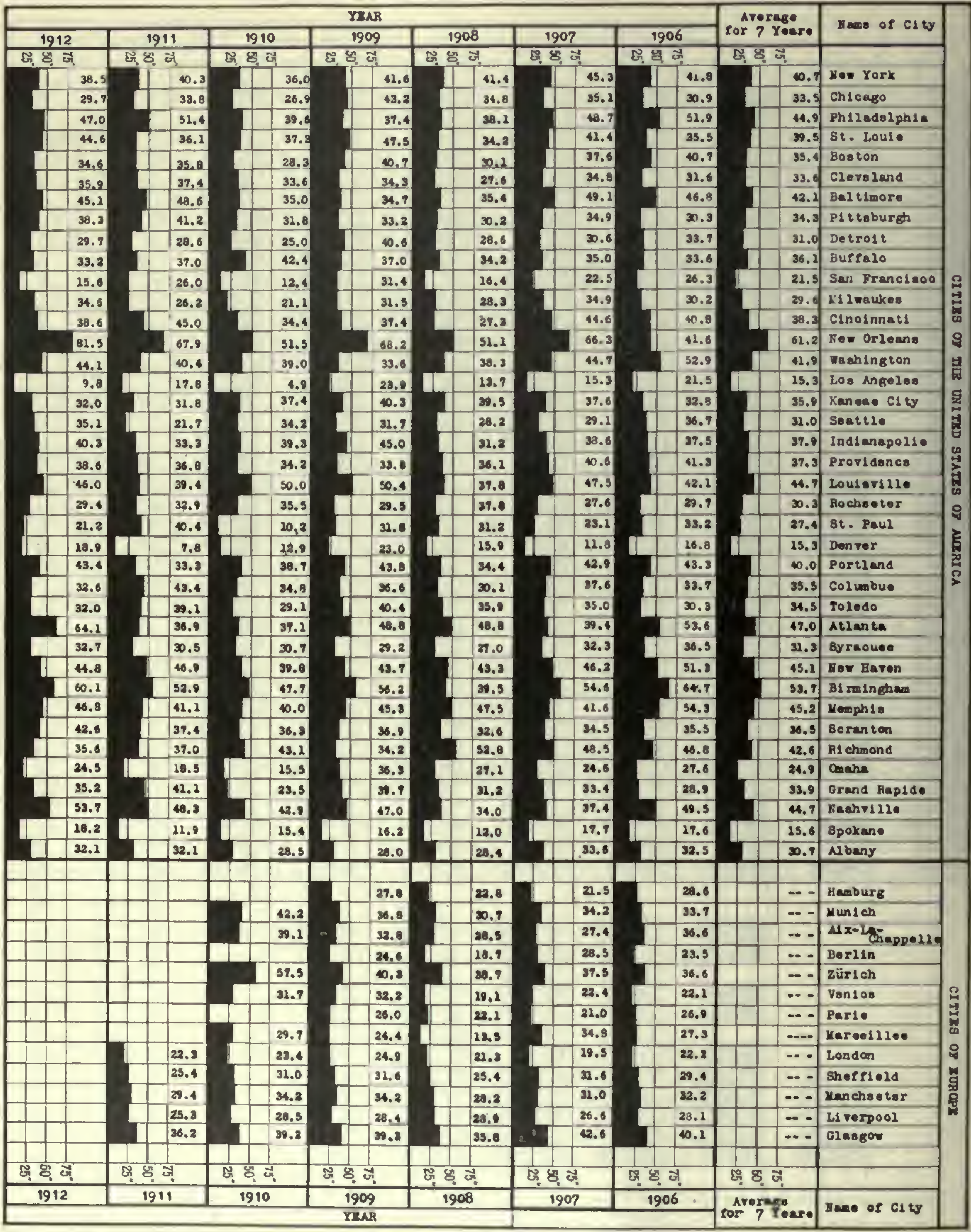
YEAR														Average for 7 Years		Name of City	
1912		1911		1910		1909		1908		1907		1906					
25 50 75		25 50 75		25 50 75		25 50 75		25 50 75		25 50 75		25 50 75		25 50 75			
44.0	59.0	46.0	60.0	46.1	60.0	45.9	59.5	46.4	60.5	44.4	58.0	46.8	60.3	45.7	59.6	New York	CITIES OF THE UNITED STATES OF AMERICA
41.4	55.4	45.3	58.7	43.8	57.4	43.2	56.2	44.7	58.7	42.5	55.7	44.8	57.3	43.7	57.1	Chicago	
46.2	62.2	47.7	63.2	47.6	62.4	47.5	62.8	47.8	63.2	45.5	60.6	47.9	62.8	47.2	62.5	Philadelphia	
46.0	63.0	49.0	66.0	47.0	64.0	47.0	65.0	49.0	66.0	47.0	63.0	48.0	64.0	47.6	64.4	St. Louis	
42.5	58.6	43.3	58.6	43.3	58.2	42.8	58.1	43.1	59.4	41.0	56.4	42.4	57.6	42.6	58.1	Boston	
41.0	55.2	44.0	57.7	42.2	55.7	42.0	55.8	42.7	58.1	40.3	55.0	43.0	57.0	42.2	56.4	Cleveland	
47.5	64.0	48.6	64.6	48.0	63.4	47.8	63.9	48.0	64.3	45.5	61.8	48.0	63.9	47.6	63.7	Baltimore	
42.4	59.4	45.1	62.3	43.8	60.3	43.6	60.7	43.9	62.5	42.2	59.2	44.2	61.5	43.6	60.8	Pittsburgh	
38.8	54.2	42.3	57.4	40.7	56.3	40.2	55.7	41.1	57.5	38.8	54.4	41.7	57.6	40.5	56.2	Detroit	
39.2	52.9	41.6	55.5	39.8	54.2	40.5	54.0	40.8	54.8	38.9	52.0	41.0	54.6	40.3	54.0	Buffalo	
54.6	62.6	49.2	61.5	49.2	61.5	49.1	61.2	48.7	61.3	50.4	61.6	49.9	62.6	50.2	61.8	San Francisco	
37.4	52.0	41.0	55.5	39.6	54.7	39.7	52.7	40.5	55.2	38.4	52.6	41.1	54.8	39.7	53.9	Milwaukee	
45.0	63.0	48.0	66.0	45.0	64.0	46.0	64.0	47.0	66.0	46.0	63.0	47.0	64.0	46.3	64.3	Cincinnati	
61.1	75.1	63.7	78.0	61.3	77.1	62.4	77.7	62.5	77.7	63.1	77.7	61.7	76.8	62.3	77.3	New Orleans	
45.0	64.0	47.0	65.8	45.8	64.3	45.7	64.8	46.0	64.8	44.2	62.8	47.1	64.6	45.8	64.4	Washington	
53.0	72.0	53.0	71.0	54.0	73.0	53.0	70.0	52.0	72.0	52.9	72.3	53.0	72.7	53.0	71.9	Los Angeles	
44.5	62.0	47.8	65.8	46.3	64.4	45.7	63.7	46.7	65.0	45.9	63.5	46.3	63.7	47.1	64.0	Kansas City	
45.1	58.0	43.6	56.9	44.6	57.2	43.3	56.0	44.3	57.5	44.4	57.7	45.6	59.4	44.4	57.5	Seattle	
42.3	59.3	45.7	63.0	43.4	60.9	43.4	60.7	45.1	63.1	43.5	60.0	44.4	61.7	44.0	61.2	Indianapolis	
40.9	57.8	41.5	58.6	41.3	58.4	40.8	58.3	41.0	59.6	39.3	56.7	41.2	49.5	40.9	57.0	Providence	
46.0	65.0	50.0	68.0	47.0	66.0	48.0	66.0	49.1	68.3	47.4	65.6	48.1	66.2	47.9	66.4	Louisville	
38.6	54.5	41.1	57.0	39.7	55.5	39.8	55.5	40.4	56.9	38.4	54.2	40.4	57.6	39.8	55.9	Rochester	
33.9	52.4	35.6	53.9	36.1	56.2	35.4	51.9	37.2	54.8	33.8	81.1	36.5	53.6	35.5	53.4	St. Paul	
35.3	60.0	37.7	63.8	39.2	66.2	36.8	61.9	37.2	63.2	37.8	64.1	37.1	62.6	37.3	63.1	Denver	
45.8	61.1	44.5	60.0	45.6	61.0	43.8	59.8	45.0	60.8	45.8	61.4	46.4	62.8	45.3	60.9	Portland	
41.8	59.8	45.0	62.6	42.7	60.7	43.0	61.0	43.9	63.1	42.0	59.6	43.9	61.6	43.2	61.2	Columbus	
39.8	56.6	43.5	59.6	41.9	58.4	41.6	57.7	42.5	59.4	40.4	56.3	42.3	58.6	41.7	58.1	Toledo	
51.9	68.4	54.0	71.7	51.8	69.4	52.7	70.2	53.0	70.4	53.1	70.3	52.8	69.5	52.8	70.0	Atlanta	
37.8	53.8	40.1	56.0	39.0	55.0	38.9	54.8	39.3	56.2	37.5	53.0	39.4	55.2	38.9	54.9	Syracuse	
42.0	58.6	42.7	59.0	42.5	58.9	42.3	58.6	42.6	59.9	40.3	57.1	42.4	59.1	42.1	58.7	New Haven	
52.1	70.6	55.2	74.4	52.9	72.1	54.4	73.0	54.6	73.6	54.8	72.5	54.6	71.7	54.1	72.6	Birmingham	
52.0	67.5	55.0	72.0	53.0	70.0	54.3	70.5	55.1	71.0	54.5	70.3	53.3	68.9	53.9	70.0	Memphis	
39.8	57.9	41.4	59.4	40.2	58.7	40.3	58.0	40.5	59.8	38.8	56.5	41.3	58.7	40.3	58.4	Scranton	
47.0	67.0	48.0	68.0	47.0	67.0	48.0	68.0	49.0	68.0	47.0	67.0	49.0	68.0	47.9	67.6	Richmond	
41.0	59.0	43.3	62.0	42.8	61.7	41.2	58.8	43.3	61.2	41.4	59.1	42.3	59.9	42.2	60.2	Omaha	
37.7	54.4	41.4	57.8	39.7	57.4	39.2	56.0	40.0	57.9	37.8	54.3	40.1	57.3	39.4	56.4	Grand Rapids	
48.0	67.0	51.0	70.0	49.0	69.0	50.0	70.0	51.0	70.0	50.0	70.0	50.0	69.0	49.9	69.3	Nashville	
38.7	57.0	37.9	57.6	40.0	59.1	37.6	57.2	39.0	58.5	37.9	57.4	39.5	59.4	38.7	58.0	Spokane	
38.8	56.3	40.2	58.0	39.6	57.4	39.7	56.9	39.8	58.3	38.3	55.6	39.6	57.7	39.4	57.2	Albany	
																Hamburg	CITIES OF EUROPE
				39.4	53.2	37.2	51.6	37.4	52.0	38.8	53.1	39.0	63.2			Munich	
				43.5	56.3	41.2	54.5	41.5	55.2	42.3	55.4	42.1	55.9			Aix-La-Chappelle	
						41.5	54.1	41.9	54.9	42.3	54.3	43.7	56.1			Berlin	
																Zurich	
																Venice	
						42.6	58.0	43.1	58.5	43.6	59.0	44.0	59.8			Paris	
				47.6	65.5	46.8	65.5	48.3	66.7	48.2	66.8	47.5	66.6			Marseilles	
		45.9	59.7	44.1	56.9	42.9	55.8	44.4	56.3	43.9	56.4	44.2	58.1			London	
		43.7	56.2	42.7	54.1	41.6	53.6	42.6	54.6	42.0	54.0	42.7	55.4			Sheffield	
		44.7	56.9	43.3	54.7	41.8	53.8	43.5	55.4	42.1	54.5	42.9	55.7			Manchester	
		45.0	55.7	44.1	53.8	42.9	52.8	44.1	53.8	43.2	53.1	43.7	54.4			Liverpool	
		43.3	53.9	42.3	52.7	41.1	51.8	43.0	53.3	41.9	51.6	42.3	52.9			Glasgow	
25 50 75		25 50 75		25 50 75		25 50 75		25 50 75		25 50 75		25 50 75		25 50 75			
1912		1911		1910		1909		1908		1907		1906		Average for 7 Years		Name of City	
YEAR																	

FIG. 63. TEMPERATURE CHANGES IN 39 AMERICAN AND 13 EUROPEAN CITIES. 1906—1912



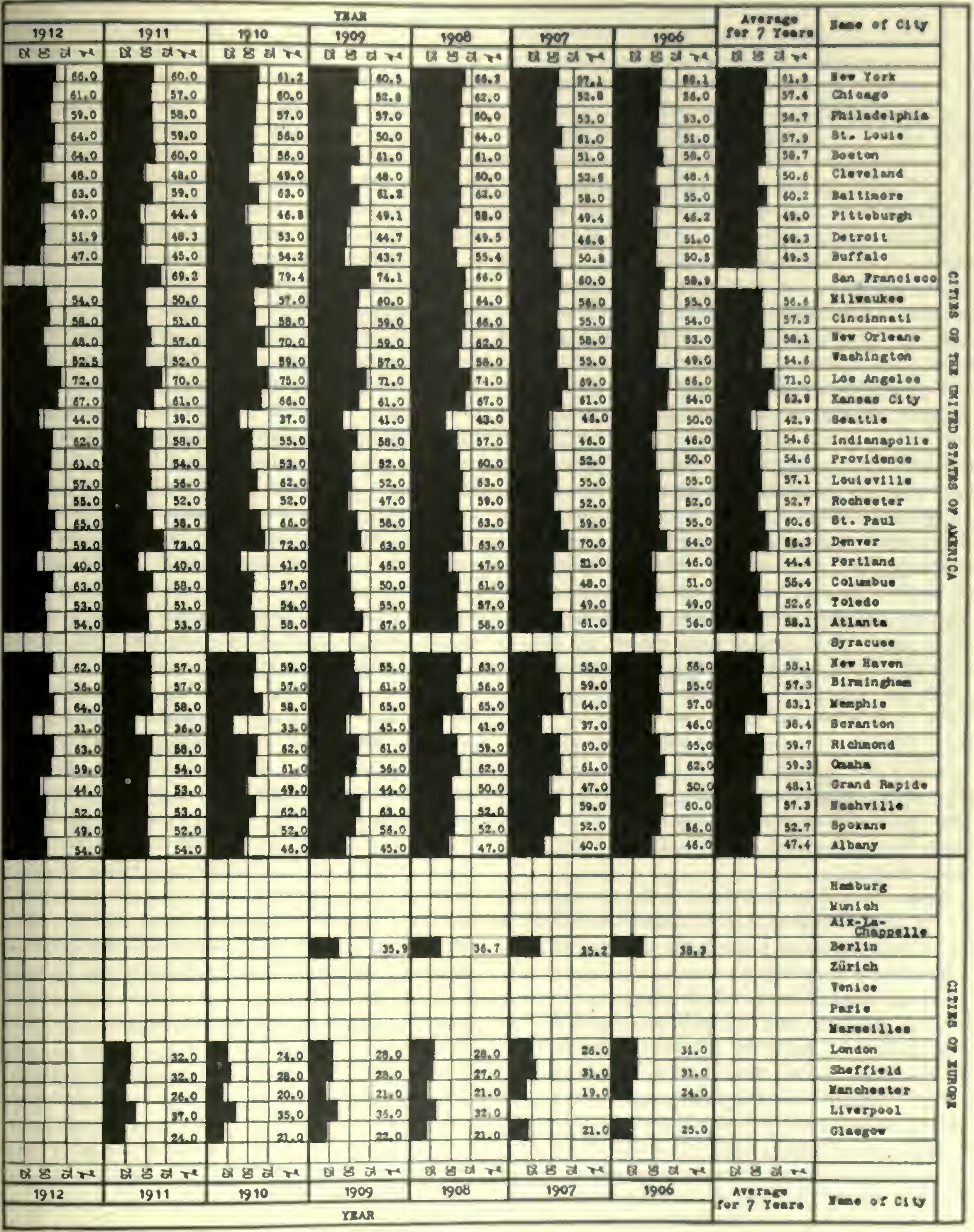
YEAR 1912	1911	1910	1909	1908	1907	1906	Average for 7 Years	Name of City	
67.0	73.0	69.0	70.0	70.0	71.0	73.0	70.4	New York	CITIES OF THE UNITED STATES OF AMERICA
71.0	72.0	73.0	76.0	75.0	76.0	76.0	74.1	Chicago	
68.5	68.9	70.7	67.2	71.7	71.8	68.1	69.6	Philadelphia	
70.5	69.0	69.0	69.0	68.0	72.0	71.0	69.8	St. Louis	
67.3	70.2	71.6	71.0	70.0	71.0	72.0	70.4	Boston	
74.0	73.0	74.0	72.8	69.4	73.0	74.0	72.9	Cleveland	
69.0	70.0	68.0	67.2	70.0	69.0	68.0	68.7	Baltimore	
70.1	69.8	70.2	69.0	67.7	71.7	72.9	70.2	Pittsburgh	
75.4	73.6	71.2	75.3	76.8	77.8	76.4	75.2	Detroit	
78.0	78.0	80.4	76.8	75.7	77.0	78.0	77.7	Buffalo	
75.0	75.0	78.0	78.0	77.0	80.0	79.0	77.4	San Francisco	
74.0	74.0	73.0	80.0	76.0	75.0	78.0	75.7	Milwaukee	
72.0	69.0	67.0	68.0	63.0	69.0	68.0	68.0	Cincinnati	
78.0	79.0	75.0	80.0	78.0	78.0	79.0	78.1	New Orleans	
70.2	70.0	69.6	68.0	71.0	75.5	73.5	71.1	Washington	
66.0	66.0	67.0	70.0	68.0	70.5	69.5	68.1	Los Angeles	
66.0	66.0	67.0	70.0	68.0	70.0	69.0	68.0	Kansas City	
78.0	77.0	82.0	80.0	81.0	78.0	75.0	78.7	Seattle	
72.0	71.0	70.0	73.0	68.0	73.0	75.0	71.7	Indianapolis	
72.6	72.7	72.0	70.5	70.5	72.5	73.0	72.0	Providence	
68.0	68.0	68.0	70.0	66.0	70.0	72.0	68.9	Louisville	
73.0	71.0	72.0	72.0	71.0	73.0	74.0	72.3	Rochester	
69.0	70.0	67.0	72.0	69.0	70.0	74.0	70.1	St. Paul	
56.0	49.0	49.0	58.0	52.0	54.0	57.0	53.6	Denver	
75.0	74.0	73.0	74.0	74.0	73.0	73.0	73.7	Portland	
74.0	71.1	70.7	72.2	68.4	73.7	72.1	71.7	Columbus	
73.0	72.0	72.0	74.0	71.0	76.0	74.0	73.1	Toledo	
74.0	72.0	69.0	71.0	73.0	70.0	72.0	71.6	Atlanta	
77.0	76.0	76.0	77.0	76.0	76.0	77.0	76.4	Syracuse	
69.0	69.0	69.0	69.0	70.0	72.0	73.0	70.1	New Haven	
74.0	72.0	72.0	73.0	72.0	73.0	76.0	73.1	Birmingham	
71.0	68.0	68.0	69.0	74.0	73.0	75.0	71.1	Memphis	
74.0	74.0	75.0	69.0	69.0	71.0	74.0	72.3	Scranton	
70.0	78.0	82.0	77.0	77.0	76.0	78.0	76.9	Richmond	
69.0	65.0	66.5	73.0	68.5	67.5	66.5	68.0	Omaha	
79.0	76.0	74.0	76.0	73.0	77.0	76.0	75.9	Grand Rapids	
73.0	72.0	71.0	74.0	71.0	71.0	71.0	71.9	Nashville	
66.0	60.0	61.0	62.0	63.0	67.0	64.0	63.3	Spokane	
74.0	72.0	73.0	71.0	71.0	75.0	74.0	72.9	Albany	
								Hamburg	CITIES OF EUROPE
		83.0	82.0	82.0	82.0	81.0		Munich	
		80.3	79.0	79.8	78.3	79.4		Aix-La-Chappell	
			77.0	76.0	78.0	76.0		Berlin	
		78.0	75.0	78.0	76.0	75.0		Zürich	
		74.3	72.4	74.9	82.9	69.4		Venice	
			76.3	79.4	77.8	77.3		Paris	
		70.8	69.3	67.0	66.1	65.6		Marseilles	
	72.3	82.5	80.6	79.9	80.9	79.1		London	
	81.5	83.3	82.2	83.5	86.3	84.0		Sheffield	
	79.8	84.3	82.0	82.9	83.1	81.7		Manchester	
	78.8	82.2	81.5	83.0	83.5	81.9		Liverpool	
	81.2	82.5	81.5	82.8	83.9	81.8		Glasgow	
1912	19111	1910	1909	1908	1907	1906 YEAR	Average for 7 Years	Name of City	

FIG. 64. RECORD OF RELATIVE HUMIDITY IN 39 AMERICAN AND 13 EUROPEAN CITIES 1906—1912



1912	1911	1910	1909	1908	1907	1906	Average for 7 Years	Name of City	
38.5	40.3	36.0	41.6	41.4	45.3	41.8	40.7	New York	CITIES OF THE UNITED STATES OF AMERICA
29.7	33.8	26.9	43.2	34.8	35.1	30.9	33.5	Chicago	
47.0	51.4	39.6	37.4	38.1	48.7	51.9	44.9	Philadelphia	
44.6	36.1	37.2	47.5	34.2	41.4	35.5	39.5	St. Louis	
34.6	35.8	28.3	40.7	30.1	37.6	40.7	35.4	Boston	
35.9	37.4	33.6	34.3	27.6	34.8	31.6	33.6	Cleveland	
45.1	48.6	35.0	34.7	35.4	49.1	46.8	42.1	Baltimore	
38.3	41.2	31.8	33.2	30.2	34.9	30.3	34.3	Pittsburgh	
29.7	28.6	25.0	40.6	28.6	30.6	33.7	31.0	Detroit	
33.2	37.0	42.4	37.0	34.2	35.0	33.6	36.1	Buffalo	
15.6	26.0	12.4	31.4	16.4	22.5	26.3	21.5	San Francisco	
34.6	26.2	21.1	31.5	28.3	34.9	30.2	29.6	Milwaukee	
38.6	45.0	34.4	37.4	27.3	44.6	40.8	38.3	Cincinnati	
81.5	67.9	51.5	68.2	51.1	66.3	41.6	61.2	New Orleans	
44.1	40.4	39.0	33.6	38.3	44.7	52.9	41.9	Washington	
9.8	17.8	4.9	23.9	13.7	15.3	21.5	15.3	Los Angeles	
32.0	31.8	37.4	40.3	39.5	37.6	32.8	35.9	Kansas City	
35.1	21.7	34.2	31.7	28.2	29.1	36.7	31.0	Seattle	
40.3	33.3	39.3	45.0	31.2	38.6	37.5	37.9	Indianapolis	
38.6	36.8	34.2	33.8	36.1	40.6	41.3	37.3	Providence	
46.0	39.4	50.0	50.4	37.8	47.5	42.1	44.7	Louisville	
29.4	32.9	35.5	29.5	37.8	27.6	29.7	30.3	Rochester	
21.2	40.4	10.2	31.8	31.2	23.1	33.2	27.4	St. Paul	
18.9	7.8	12.9	23.0	15.9	11.8	16.8	15.3	Denver	
43.4	33.3	38.7	43.8	34.4	42.9	43.3	40.0	Portland	
32.6	43.4	34.8	36.6	30.1	37.6	33.7	35.5	Columbus	
32.0	39.1	29.1	40.4	35.9	35.0	30.3	34.5	Toledo	
64.1	36.9	37.1	48.8	48.8	39.4	53.6	47.0	Atlanta	
32.7	30.5	30.7	29.2	27.0	32.3	36.5	31.3	Syracuse	
44.8	46.9	39.8	43.7	43.3	46.2	51.3	45.1	New Haven	
60.1	52.9	47.7	56.2	39.5	54.6	64.7	53.7	Birmingham	
46.8	41.1	40.0	45.3	47.5	41.6	54.3	45.2	Memphis	
42.6	37.4	36.3	36.9	32.6	34.5	35.5	36.5	Scranton	
35.6	37.0	43.1	34.2	52.8	48.5	46.8	42.6	Richmond	
24.5	18.5	15.5	36.3	27.1	24.6	27.6	24.9	Omaha	
35.2	41.1	23.5	39.7	31.2	33.4	28.9	33.9	Grand Rapids	
53.7	48.3	42.9	47.0	34.0	37.4	49.5	44.7	Nashville	
18.2	11.9	15.4	16.2	12.0	17.7	17.6	15.6	Spokane	
32.1	32.1	28.5	28.0	28.4	33.6	32.5	30.7	Albany	
			27.8	22.8	21.5	28.6	-- -	Hamburg	CITIES OF EUROPE
		42.2	36.8	30.7	34.2	33.7	-- -	Munich	
		39.1	32.8	28.5	27.4	36.6	-- -	Aix-La-Chappelle	
			24.6	18.7	28.5	23.5	-- -	Berlin	
		57.5	40.3	38.7	37.5	36.6	-- -	Zürich	
		31.7	32.2	19.1	22.4	22.1	-- -	Venice	
			26.0	22.1	21.0	26.9	-- -	Paris	
		29.7	24.4	13.5	34.8	27.3	----	Marseilles	
	22.3	23.4	24.9	21.3	19.5	22.2	-- -	London	
	25.4	31.0	31.6	25.4	31.6	29.4	-- -	Sheffield	
	29.4	34.2	34.2	28.2	31.0	32.2	-- -	Manchester	
	25.3	28.5	28.4	28.9	26.6	28.1	-- -	Liverpool	
	36.2	39.2	39.3	35.8	42.6	40.1	-- -	Glasgow	

FIG. 65. RECORD OF PRECIPITATION IN 39 AMERICAN AND 13 EUROPEAN CITIES. 1906—1912



1912	1911	1910	1909	1908	1907	1906	Average for 7 Years	Name of City	
66.0	60.0	61.2	60.3	66.3	57.1	58.1	61.3	New York	CITIES OF THE UNITED STATES OF AMERICA
61.0	57.0	60.0	52.8	62.0	52.8	56.0	57.4	Chicago	
59.0	58.0	57.0	57.0	60.0	53.0	53.0	56.7	Philadelphia	
64.0	59.0	56.0	50.0	64.0	61.0	51.0	57.9	St. Louis	
64.0	60.0	56.0	61.0	61.0	51.0	58.0	58.7	Boston	
48.0	48.0	49.0	48.0	60.0	52.6	48.4	50.6	Cleveland	
63.0	59.0	63.0	61.2	62.0	58.0	55.0	60.2	Baltimore	
49.0	44.4	46.8	49.1	58.0	49.4	46.2	49.0	Pittsburgh	
51.9	48.3	53.0	44.7	49.5	46.6	51.0	49.3	Detroit	
47.0	45.0	54.2	43.7	55.4	50.8	50.5	49.5	Buffalo	
	69.2	79.4	74.1	66.0	60.0	58.9		San Francisco	
54.0	50.0	57.0	60.0	64.0	56.0	55.0	56.6	Milwaukee	
58.0	51.0	58.0	59.0	66.0	55.0	54.0	57.3	Cincinnati	
48.0	57.0	70.0	59.0	62.0	58.0	53.0	58.1	New Orleans	
52.5	52.0	59.0	57.0	58.0	55.0	49.0	54.6	Washington	
72.0	70.0	75.0	71.0	74.0	69.0	66.0	71.0	Los Angeles	
67.0	61.0	66.0	61.0	67.0	61.0	64.0	63.9	Kansas City	
44.0	39.0	37.0	41.0	43.0	46.0	50.0	42.9	Seattle	
62.0	58.0	55.0	58.0	57.0	46.0	46.0	54.6	Indianapolis	
61.0	54.0	53.0	52.0	60.0	52.0	50.0	54.6	Providence	
57.0	56.0	62.0	52.0	63.0	55.0	55.0	57.1	Louisville	
55.0	52.0	52.0	47.0	59.0	52.0	52.0	52.7	Rochester	
65.0	58.0	66.0	58.0	63.0	59.0	55.0	60.6	St. Paul	
59.0	73.0	72.0	63.0	63.0	70.0	64.0	66.3	Denver	
40.0	40.0	41.0	46.0	47.0	51.0	46.0	44.4	Portland	
63.0	58.0	57.0	50.0	61.0	48.0	51.0	55.4	Columbus	
53.0	51.0	54.0	55.0	57.0	49.0	49.0	52.6	Toledo	
54.0	53.0	58.0	67.0	58.0	61.0	56.0	58.1	Atlanta	
								Syracuse	
62.0	57.0	59.0	55.0	63.0	55.0	56.0	58.1	New Haven	
56.0	57.0	57.0	61.0	56.0	59.0	55.0	57.3	Birmingham	
64.0	58.0	58.0	65.0	65.0	64.0	57.0	63.1	Memphis	
31.0	36.0	33.0	45.0	41.0	37.0	46.0	38.4	Scranton	
63.0	58.0	62.0	61.0	59.0	60.0	65.0	59.7	Richmond	
59.0	54.0	61.0	56.0	62.0	61.0	62.0	59.3	Omaha	
44.0	53.0	49.0	44.0	50.0	47.0	50.0	48.1	Grand Rapids	
52.0	53.0	62.0	63.0	52.0	59.0	60.0	57.3	Nashville	
49.0	52.0	52.0	56.0	52.0	52.0	56.0	52.7	Spokane	
54.0	54.0	46.0	45.0	47.0	40.0	46.0	47.4	Albany	
								Hamburg	CITIES OF EUROPE
								Munich	
								Aix-la-Chappelle	
			35.9	36.7	25.2	38.3		Berlin	
								Zürich	
								Venice	
								Paris	
								Marseilles	
	32.0	24.0	28.0	28.0	26.0	31.0		London	
	32.0	28.0	28.0	27.0	31.0	31.0		Sheffield	
	26.0	20.0	21.0	21.0	19.0	24.0		Manchester	
	37.0	35.0	36.0	32.0				Liverpool	
	24.0	21.0	22.0	21.0	21.0	25.0		Glasgow	

FIG. 66. MAXIMUM AND AVERAGE PERCENTAGE OF SUNSHINE IN 39 AMERICAN AND 13 EUROPEAN CITIES. 1906—1912

employed in making observations. Mean weather conditions as established for various cities do not in all cases serve to disclose climatic differences. For example, the average weather conditions in Chicago are similar to those in Seattle, especially with regard to temperature and precipitation, yet in regard to climate these two cities are known to be widely dissimilar. Chicago's precipitation is well distributed throughout the year, while that of Seattle occurs almost wholly during the colder months. The temperature range of Chicago is nearly twice as great as that of Seattle. A comparison of the mean maximum and mean minimum temperatures of London and Chicago presents similar inconsistencies when the extremes and ranges of temperature are considered.

Again, data as reported for different cities are not always comparable, because of differences in the methods employed in making observations or in the instruments used in recording effects. In general, however, data for various cities in the United States are obtained by means of methods and instruments which are identical or similar, so that the records for cities in this country are generally directly comparable with each other. But comparisons cannot be drawn with the same certainty between European and American cities. For instance, the sunshine values for European cities are uniformly lower than those for cities of the United States, a discrepancy due in part to the fact that thermometric recording instruments are employed by all the United States Weather Bureau offices, while most European cities use the photographic sunshine recorder.

Notwithstanding limitations of the sort referred to, the record supplies a good basis from which to study meteorological phenomena in their relation to atmospheric pollution.

113.03 Wind Movement: Wind velocities both in this country and abroad are recorded in practically all cases by means of instruments which are identical, the Robinson anemometer being in general use for this purpose. But the records are affected by differences in the character of exposure at the points of observation. An anemometer records the wind movement at the precise point of its location, and such instruments installed at several points in the same city may record different values. For example, during the period from 1891 to 1905 the Chicago weather office was located in the Auditorium Tower and its anemometer had a free exposure for several blocks in every direction. Under these conditions the recorded wind movement averaged 17.0 miles per hour. Since 1906 the office has been in the Federal Building on the dome of which the anemometer is located. The present point of exposure is 36 feet higher than the former location, but there are lofty buildings closely surrounding it. The average movement of air over the dome of the Federal Building from 1906 to 1912, inclusive, was but 14.0 miles per hour, or 18 per cent less than at the Auditorium. A comparison of simultaneous records of wind movement made at the Auditorium Tower and at the Federal Dome for a period of six months from July to December, 1905, inclusive, discloses the fact that the wind velocity at the Federal Dome averaged only 90 per cent of that at the Auditorium Tower, the velocity being less for movements from all points of the compass except from the west and northwest, in which cases it was slightly higher at the Federal Dome. The change in the annual average wind velocities as shown by the records of the Chicago office is not due, therefore, to an actual change in the wind movement at Chicago, but is the result of a change in the location of the point of exposure of the instruments.

The record (fig. 62) indicates that there has been a steady increase in the wind velocity at New York City, the average for 1910 being 11.6 miles per hour and that for 1912, 17.7 miles per hour. In 1907 the average hourly velocity at New York was 11.7 miles and at Chicago 14.5 miles; in 1912 the relation was reversed and the average velocities were 17.7 and 13.0 miles respectively. The increase at New York has been due to the removal of the anemometer to the top of one of the highest buildings in the city, its elevation now being 454 feet, or 104 feet higher than in 1910.

Experiments conducted by Prof. Henry J. Cox for a period of six months in 1907 in the moorlands of Wisconsin showed that the velocity of the wind at a point 4.7 feet above the ground averaged 4.5 miles per hour, while at an elevation of 50 feet above the ground at the same location the average recorded was 9.0 miles per hour, the increase in velocity due to the difference in elevation being 100 per cent. The wind velocity recorded on the

Eiffel Tower at a point 990 feet above ground is 3.1 times that recorded at the same location at an altitude of only 60 feet. Thus, wind velocity varies directly with the elevation of the point of observation above the ground. However, if the point of observation is surrounded by structures of greater height, the wind velocity recorded may be less than that for a lower point which is not so surrounded. Were it possible to establish conditions in every city which would provide the same relative exposure for the recording instruments, the resulting values would fairly represent the wind movements in the various sections. The only differences under such conditions would be due to the configuration of the country and the proximity of the point of observation to paths of storms.

The intensity of fogs, other things being equal, may be said to vary inversely with the velocity of wind movements. In London, where the prevailing light winds are insufficient to carry away the smoke of the city, fogs are of far greater frequency than in most other cities. Along the Gulf Coast and the Pacific Coast the prevailing winds are from water surfaces, a factor which is favorable to the formation of fogs. In the large cities of the Atlantic Coast the prevailing winds are from the land. As a result, the atmosphere of the Atlantic Coast cities is less humid and conditions are less favorable to the formation of fogs than is the case along the Gulf Coast and the Pacific Coast. At Chicago, Buffalo and other lake cities, during the colder season, the moisture laden winds from the lakes are frequently too light to dispel the smoke. This condition is favorable for the formation of fogs.

The wind movement is, on the average, greater in the northern states than in the southern. The storm movement in the north is more active than in the south, and brisk winds in the north usually accompany precipitation and sharp changes in temperature.

From the foregoing, it is evident that atmospheric pollution due to the products of combustion is diminished directly in proportion to the velocity of the wind. With no wind, those products of combustion which are lighter than air move very slowly into the upper strata of the atmosphere, while the heavier products, including dust, ash and soot, are deposited upon every accessible surface.

Chicago is fortunate in being situated close to certain well defined storm tracks which are responsible for winds of higher velocity than the average throughout the country. Moreover, Chicago's advantage lies not only in the fact that maximum velocities are higher, but in the fact that the average hourly velocities in Chicago are greater than those of most other American cities. The seven-years' record for 39 American cities (fig. 62) shows that the average wind velocities for Chicago were exceeded by those of only three other cities, namely, Toledo, Cleveland and Buffalo. For Chicago the average was 14 miles per hour, for Toledo 14.1 miles per hour and for Cleveland and Buffalo 14.6 miles per hour. For more than half of the cities reporting it was less than 10 miles per hour. Chicago's breezes generally dispel the smoke produced within the city and its environs. In the maintenance of the purity of its atmosphere Chicago has a distinct advantage over most other cities. The cleansing effects of its winds are nearly double those of Baltimore, New Orleans and the more important cities of the Pacific Coast.

113.04 Temperature:* As factors affecting the extent to which products of combustion pollute the atmosphere, temperature and temperature changes are almost as important as the wind movement.

It has not been possible to make a satisfactory comparison between the recorded temperatures of European cities and those of cities in the United States, owing to the fact that complete data for the former are not available. It is evident, however, that the temperature recorded in the British Isles and along the western coast of the continent of Europe corresponds roughly with that of cities along the Pacific Coast of the United States. The range of temperature at points along the coast is not great, while that for interior points both in Europe and in the United States is considerable. This difference between interior points and points near the sea coast is due largely to the influence of ocean currents. The average annual range of temperature at Chicago is 106 degrees, at New York 94 degrees, at Denver 113 degrees and at San Francisco only 53 degrees. The range of temperature also decreases from north to south, the average annual range being 120

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* All temperature values are expressed in degrees Fahrenheit.

degrees at Duluth, 87 degrees at Memphis and 70 degrees at New Orleans.

Cities located on the Great Lakes and exposed to the influence of the lake breezes are comparatively free from periods of extreme heat. Even during the record breaking summer of 1911, the number of days during which the temperature reached 90 degrees or above was, at Buffalo 5, at Chicago 22, at Milwaukee 15, at Detroit 14, at Toledo 18, and at Cleveland 6. Cities on the plains, remote from the lakes, show much higher maximum temperatures, Kansas City having, in 1911, 50 days with a maximum temperature of 90 degrees or above, Omaha 52 and St. Louis 43. In the East, Boston and New York had 13 and 8 such days, respectively. In the South, New Orleans, Birmingham and Atlanta had 59, 61 and 37 such days, respectively. In the foothills of the Rocky Mountains, Denver had 15, while Seattle had 2, San Francisco none and Los Angeles 9. In the year 1912, Chicago had 16 days during which a temperature of zero or lower was recorded, Buffalo had 9, Milwaukee 26, Detroit 14, Cleveland 12, Toledo 10, Kansas City 11, St. Louis 11, Omaha 20, Boston 5 and New York 3, while Denver had 7 and the Pacific Coast cities and the southern cities previously mentioned had none.

The mean temperature recorded at Chicago is, as a rule, somewhat higher than that recorded at other cities in the southern lake region. This is probably due to the fact that the Chicago weather office is located in the very midst of the business district of a large city, where the activities are intense and the heat given off by the buildings is appreciable. If it were possible to make comparisons of the temperatures of the suburbs of the various lake cities, the differences would doubtless not be great. When the Chicago weather office was located in the Auditorium Tower near the lake shore, the average temperature was about 1.7 degrees lower than that recorded at the present office in the Federal Building.

The relation which exists between temperature and the extent to which products of combustion pollute the atmosphere is indirect rather than direct. Temperature operates to affect other meteorological phenomena, including wind movement and relative humidity, and in this manner has an important bearing upon atmospheric pollution. A relatively high temperature generally produces a dry atmosphere, a condition unfavorable to atmospheric pollution; a low temperature induces a condition of humidity which serves generally to intensify atmospheric pollution. In Chicago, smoke is most effective as a source of atmospheric pollution during periods, usually in the winter, when a low temperature is accompanied by a light wind movement or by the entire absence of wind.

113.05 Relative Humidity: The term "humidity" is employed in referring to the quantity of moisture in the form of invisible vapor present in the air. The air is said to be dry when little moisture is present and humid when the quantity of moisture is relatively great. If the quantity of moisture is expressed in units of weight per unit of volume, as, for example, grains per cubic foot, the numerical value is designated as the absolute humidity. If, as is common in statistics relating to weather conditions, the value is expressed in percentage of the quantity of vapor which the atmosphere will retain at the temperature recorded, this value is known as the relative humidity.

The relative humidity of the atmosphere of cities in western Europe, especially in the British Isles, is considerably higher than that of Chicago. At Munich, on the northern slope of the Bavarian Alps, the humidity is considerably higher in winter than in summer because of persistent cloudiness and snow flurries during the winter, and the average annual humidity is comparatively high for that reason. At Venice and at Marseilles, where the humidity is lower than at other European cities for which data are available, there is a wide variation between the summer and the winter values; the humidity at Venice especially is often high for protracted periods during the colder season of the year.

London is noted for its fogs. Aitken says of them: "When we have fogs the atmosphere is nearly saturated with vapor, and the smoke particles, being good radiators, are soon cooled and form nuclei on which the vapor condenses. The smoke particles thus become loaded with moisture which prevents them from rising, and by sinking into our streets add their murky thickness to the foggy air. That the color or blackness of what is called a 'pea-soup' fog is due to smoke is, I think, evident from the fact that a town fog enters our houses and carries its murky thickness into our rooms, and will not be induced to make itself invisible however warmly we treat it. It will on no account dissolve into thin air, however warm our rooms, for the simple reason that heat only dissolves the moisture and leaves the smoke, which constitutes a room fog, to settle slowly and soil and destroy the furniture. If the fog was pure, that is to say, a true fog and nothing but a fog, such as one sees in the country, it would dissolve when heated, as every well-conditioned country fog does,—at least, I never remember meeting a fog in a country house."

Relative humidity in dense fog is usually 100 per cent, but occasionally, in the midst of large cities, oily vapors discharged from innumerable chimneys condense upon the fog particles and prevent evaporation even when the humidity of the air is considerably below the saturation point. Possible instances of this kind occurred at Chicago on September 10, 1888, and on October 18, 1889, when the records of the weather office show dense fog with relative humidities of 52 and 58 per cent, respectively. Fogs in Chicago are sometimes blown in from the lake, but in winter they are usually caused by warm air coming in contact with snow covered ground, or, after a severe cold spell, by moist lake winds blowing over the colder surfaces of the ground whether snow covered or bare. Fogs which are dense at night may sometimes be wholly or partially dissipated upon the coming of the day with its higher temperature, but may become dense again the following night. It is not often, however, that fogs continue in Chicago through a period of 24 hours. Fogs occur with greatest frequency in March and with least frequency in July.

The average relative humidity at different cities on the Great Lakes varied but little for the seven-year period, 1906 to 1912, inclusive. The lowest was 72.9 per cent at Cleveland and the highest 77.7 per cent at Buffalo. Chicago occupied an intermediate position with an average relative humidity of 74.1 per cent. Average relative humidity is generally highest in winter and lowest in summer. The humidity of the atmosphere of cities located on the plains is usually lower than that of lake cities or of cities in the neighborhood of large bodies of water. In the foothills of the Rocky Mountains it is still lower, the annual average relative humidity at Denver, for instance, being only 53.6 per cent. At points along the Gulf of Mexico and the Pacific Coast the humidity of the atmosphere is relatively high, owing to the fact that the prevailing winds blow across water surfaces and are moist. In the cities of the Atlantic Coast, relatively dry atmospheric conditions obtain because the prevailing winds are from the land instead of from the ocean.

At Chicago the extreme monthly average values for relative humidity for a long period of years are 82.3 per cent for January and 70.4 per cent for July. Occasionally, very low humidity readings have been reported at Chicago, as, for instance, on October 21, 1871, when the relative humidity at 3:00 P.M. with a temperature of 71 degrees was 20 per cent, and on April 25, 1872, when the relative humidity at the same hour with a temperature of 81 degrees was 19 per cent. So far as is known, the latter is the lowest value for relative humidity ever recorded at Chicago. In the spring the prevailing winds which are from the lake tend to produce conditions under which the air attains its purest state. The atmosphere is not as moist as during the winter period because the temperature, as the air currents advance from the lake over the warmer surface of the land, is rising, and as a consequence the relative humidity is decreasing.

In the winter, when the temperature of the land is relatively low and the wind movement from the lake develops a condition of relatively high humidity, the air in Chicago attains a state particularly conducive to an increase in the effects of atmospheric pollution. Under such conditions fogs often develop rapidly. In most cases fogs become apparent in the business sections of the city more quickly than in the outlying districts, a condition which may be attributed, no doubt, to the fact that the smoke is densest near the centers of greatest activity. In Chicago it happens occasionally in cold weather that a combination of heavy clouds, fog and smoke hangs over the city for a period of several hours, thereby producing a condition of darkness. On such dark days it is sometimes necessary to use the street lighting system as at night. The intensity of such conditions, however, is never as aggravated in

Chicago as in London, where the fogs are often so dense as to interfere with traffic. Dense fogs occur in Chicago only when the wind is too light to dispel the smoke and the humidity of the atmosphere is high. At such periods the dust and soot particles become coated with moisture and settle to the strata near the surface of the earth, while the heavy clouds above prevent immediate dissipation by the heat of the sun. Seldom does this condition continue past midday, when the wind usually attains a velocity sufficient to relieve the situation. The record shows that during the period from 1902 to 1912, inclusive, there were 45 dark days, 11 of which were marked with pronounced darkness. Three periods of darkness with relatively high temperature have been recorded during the summer months, these having been caused by the presence of heavy clouds and smoke accompanying a thunder storm. In all cases the humidity on dark days was relatively high, rarely below 90 per cent. The most favorable atmospheric conditions for periods of darkness in Chicago have been shown to include a light easterly wind, a comparatively low temperature, a moist atmosphere with relative humidity above 90 per cent, heavy clouds overhead and dense smoke which under such conditions is not permitted to escape into the upper strata of the atmosphere. A record of the dates of dark days in Chicago during the period 1902 to 1912 and of the weather conditions obtaining in each case is presented in the following:

1902

December 10: Light variable winds throughout the day diminishing in velocity toward the evening; temperature 32 degrees* to 35 degrees; relative humidity† 98 per cent in the morning and 86 per cent in the evening; heavy clouds and dense smoke during the entire day.

1903

November 28: Light variable winds in the morning increasing in velocity toward the evening; temperature 24 degrees to 31 degrees; humidity in the morning 94 per cent and in the evening 89 per cent; light snow flurries until 1:00 P.M., heavy clouds and smoke; darkness in the loop district from 12:00 M. to 12:20 P.M., the area of darkness beginning at a point west of the Chicago River at 11:30 A. M. and shifting its position toward the lake with a change of wind direction.

1904

January 6: Light variable winds during the entire day; temperature 21 degrees to 30 degrees rising throughout the day; humidity in the morning 93 per cent and in the evening 88 per cent; snow flurries, heavy clouds and dense smoke; darkness from 7:15 A.M. to 9:30 A.M.

January 12: Light winds during the entire day; temperature 25 degrees to 34 degrees variable throughout the day; humidity in the morning 93 per cent and in the evening 94 per cent; snow flurries, heavy clouds and dense smoke; darkness from 8:00 A.M. to 9:00 A.M.

April 9: Light variable winds; northeasterly in the morning and northwesterly in the afternoon and evening; temperature 33 degrees to 40 degrees rising throughout the day; humidity in the morning 95 per cent and in the evening 88 per cent; light showers and snow flurries; heavy clouds and dense smoke causing a condition of darkness at 1:00 P.M.

July 27: Variable winds; thunder storm; temperature 62 degrees to 80 degrees variable; humidity in the morning 89 per cent, in the evening 73 per cent; heavy clouds and smoke in the afternoon, the presence of which produced a condition of darkness.

December 13: Light variable winds from the south and southwest; temperature 27 degrees to 19 degrees falling throughout the day; humidity throughout the day 90 per cent; snow flurries, heavy clouds and dense smoke; period of darkness from 7:30 A.M. to 9:00 A.M.

December 14: Light variable winds; temperature 16 degrees to 24 degrees rising; humidity in the morning 90 per cent, in the evening 74 per cent; snow flurries, heavy clouds and smoke; darkness throughout the forenoon.

1905

January 6: Light northeasterly winds; temperature 22 degrees to 30 degrees variable; humidity in the morning 86 per cent, in the evening 74 per cent; low clouds, snow flurries and heavy smoke; darkness from 11:00 A.M. to 2:00 P.M.

January 23: Light easterly winds; temperature 13 degrees to 22 degrees rising throughout the day; humidity in the morning 96 per cent, in the evening 92 per cent; light snow, low clouds and smoke; darkness from daybreak to 9:00 A.M., continuing dark on the West Side until noon.

February 4: Light variable winds; temperature 10 degrees to 18 degrees rising; humidity in the morning 90 per cent, in the evening 72 per cent; heavy clouds and smoke; darkness during the forenoon.

October 18: Moderate southwest winds shifting to northerly at 9:00 A.M.; temperature 68 degrees to 52 degrees falling throughout the day; humidity in the morning 91 per cent, in the evening 85 per cent; rain and heavy clouds· darkness from 8:40 A.M. to 9:00 A.M.

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* Fahrenheit.

† All readings of relative humidity reported in this record were taken at 7 A. M. or at 7 P. M.

November 13: Brisk to high northeast winds; temperature 57 degrees to 31 degrees, falling; humidity in the morning 85 per cent, in the evening 77 per cent; heavy clouds in the afternoon; darkness after 3:00 P.M.

December 17, 18 and 19: Light southwest winds on the 17th, light variable winds on the 18th and light westerly winds on the 19th; temperature during the three days, 30 degrees to 41 degrees variable; humidity 84 per cent to 95 per cent; low clouds and smoke; darkness during entire three days except during the forenoon of the 18th.

December 28: Moderate southwest winds; temperature 42 degrees to 37 degrees variable; humidity in the morning 65 per cent, in the evening 94 per cent; rain and low clouds; darkness during afternoon.

1906

January 21: Light variable winds; temperature 62 degrees to 31 degrees falling; humidity in the morning 96 per cent, in the evening 94 per cent; rain and fog; darkness at 1:00 P.M.

February 5 and 6: Light variable winds; temperature 15 degrees to 7 degrees on the 5th and 15 degrees to 9 degrees on the 6th; humidity on both days, 82 per cent to 85 per cent; snow on both days; heavy clouds and smoke; darkness on the 5th, continuous from 10:30 A.M. to 11:30 A.M. and on the 6th from 10:30 A.M. to 1:30 P.M.

February 13: Light variable winds shifting to northeast and increasing in velocity after 3:00 P.M.; temperature 43 degrees to 29 degrees falling; humidity in the morning 81 per cent, in the evening 90 per cent; light rain, heavy clouds, fog and smoke; darkness from 11:00 A.M. to 3:00 P.M.

February 23: Moderate northerly winds in forenoon, becoming light and variable in the afternoon; temperature 48 degrees to 40 degrees falling; humidity in the morning 86 per cent, in the evening 92 per cent; clouds and smoke during the late afternoon caused darkness.

March 2: Moderate southeast winds; temperature 49 degrees to 37 degrees variable; humidity in the morning 88 per cent, in the evening 96 per cent; rain, low clouds, light fog and smoke; the period of darkness covered the entire day.

March 7: Light variable winds shifting to the southwest and increasing in velocity in the afternoon; temperature 34 degrees to 40 degrees variable; humidity in the morning 91 per cent, in the evening 84 per cent; low clouds, dense fog and dense smoke; darkness from daybreak to 11:30 A.M.

December 11: Light variable winds; temperature 31 degrees to 40 degrees rising; humidity in the morning 78 per cent, in the evening 64 per cent; low clouds and dense smoke; darkness throughout the forenoon.

December 13: Light variable winds; temperature 43 degrees to 49 degrees variable; humidity in the morning 91 per cent, increasing in the evening to 100 per cent; light rain, low clouds, light fog and smoke; continuous darkness in the afternoon.

December 18: Light variable winds; temperature 21 degrees to 28 degrees variable; humidity in the morning 85 per cent, in the evening 69 per cent; snow, low clouds and smoke; darkness from daybreak to 10:00 A.M.

December 20: Light southerly winds; temperature 25 degrees to 32 degrees rising; humidity in the morning 92 per cent, in the evening 86 per cent; low clouds and smoke; darkness from daybreak until 9:00 A.M.

December 24: Light variable winds; temperature 22 degrees to 30 degrees variable; humidity in the morning 91 per cent, in the evening 93 per cent; snow flurries, low clouds and smoke; darkness from daybreak until 9:00 A.M. and after 3:30 P.M.

1907

January 29: Light variable winds; temperature 17 degrees to 28 degrees rising; humidity in the morning 92 per cent, in the evening 100 per cent; light snow flurries, low clouds and smoke; darkness after 3:00 P.M.

March 26: Light variable winds; temperature 45 degrees to 70 degrees variable; humidity in the morning 87 per cent, in the evening 73 per cent; low dense clouds; thunder storm in the afternoon; continuous darkness from 3:30 P.M. to 3:37 P.M.

September 18: Light variable winds; temperature 67 degrees to 75 degrees variable; humidity throughout the day 95 per cent; rain and low clouds; light fog and smoke; darkness from 8:30 A.M. until 10:00 A.M.

December 4: Light variable winds; temperature 33 degrees to 24 degrees falling; humidity throughout the day 76 per cent; snow flurries, low clouds and smoke; darkness from 1:30 P.M. until 2:30 P.M.

December 17: Light variable winds; temperature 26 degrees to 36 degrees variable; humidity in the morning 79 per cent, increasing in the evening to 86 per cent; low clouds and smoke; darkness continuous during greater portion of the day.

1908

January 3: Light variable winds shifting to southerly and increasing in velocity; temperature 20 degrees to 41 degrees rising; humidity in the morning 91 per cent, in the evening 78 per cent; low clouds and dense smoke; darkness from daybreak until 9:00 A.M.

March 27: Moderate northeast winds, shifting to easterly and becoming light in the afternoon; temperature 33 degrees to 63 degrees variable; humidity in the morning 97 per cent, in the evening 93 per cent; rain, low clouds, light fog and smoke; darkness from 9:45 A.M until 10:00 A.M. and from 3:30 P.M. until 4:00 P.M.

1909

June 4: Light variable winds; temperature 55 degrees to 69 degrees rising; humidity in the morning 96 per cent, in the evening 81 per cent; thunder storm and heavy clouds; dense fog and smoke; darkness from 8:15 A.M. until 8:45 A.M.

August 27: Light to moderate variable winds; temperature 71 degrees to 83 degrees variable; humidity in the morning 83 per cent, in the evening 95 per cent; thunder storm in the afternoon, low clouds; darkness from 12:45 P.M. until 1:15 P.M.

1910

April 16: Light variable winds in the forenoon increasing to brisk winds in the afternoon; temperature 65 degrees to 36 degrees falling; humidity in the morning 91 per cent, in the evening 88 per cent; rain and low clouds; darkness from 1:05 P.M. until 1:10 P.M.

April 22: Light variable winds increasing in velocity and shifting to northwest after 4:20 P.M.; temperature 65 degrees to 35 degrees falling; humidity in the morning 75 per cent, in the evening 97 per cent; low clouds; darkness from 4:00 P.M. until 4:20 P.M.

September 12: Moderate northerly winds; temperature 72 degrees to 58 degrees falling; humidity in the morning 93 per cent, in the evening 88 per cent; rain, low clouds and smoke; darkness from 7:00 A.M. until 7:30 A.M.

1911

January 11: Moderate northerly winds increasing in velocity as day advanced; temperature 50 degrees to 35 degrees falling; humidity in the morning 94 per cent, in the evening 93 per cent; light rain and fine mist; low clouds, light fog and smoke; darkness from 8:30 A.M. until 9:15 A.M.

March 29: Light variable winds increasing in velocity and shifting to westerly at 11:00 A.M.; temperature 30 degrees to 41 degrees rising; humidity in the morning 97 per cent, in the evening 70 per cent; low clouds, light fog and smoke; darkness continuous from 9:45 A.M. until 11:00 A.M.

December 15: Light southerly winds; temperature 32 degrees to 41 degrees rising; humidity in the morning 84 per cent, in the evening 76 per cent; dense fog and smoke; darkness from 7:00 A.M. until 10:17 A.M.

1912

January 26: Light variable winds; temperature 24 degrees to 29 degrees variable; humidity in the morning 73 per cent, in the evening 80 per cent; snow, low clouds and heavy smoke; darkness during the entire afternoon.

From a study of the facts, as set forth in the preceding discussion, it is evident that a condition of relatively high humidity is perhaps the most important medium through which the polluting effects of products of combustion may be intensified. The record indicates that the average relative humidity of Chicago's atmosphere is not higher than that of most other cities similarly located, and hence that the effects of smoke are not made relatively more objectionable as a result of this factor.

113.06 Precipitation: Precipitation is usually a natural consequence of rising humidity and favorable conditions of wind and temperature. It is an effective agent in the purification of the atmosphere.

The rainfall of the larger cities of Europe is considerably less than that of the great cities of this country. This difference is not due to the fact that the rainfall in general throughout those countries is less, but to the fact that the rain bearing winds are partly shut off from the great cities of Europe by mountains or "downs." The average annual rainfall at London, for instance, is less than 23 inches and at Glasgow less than 40 inches, while in the highlands of Scotland it ranges from 60 to 80 inches. The cities of Hamburg, Berlin and Paris are situated much the same as London with respect to rain bearing winds.

In the United States, as a rule, precipitation diminishes from the Atlantic Coast westward across the central valleys to the Rocky Mountains and the Plateau Region and from the Gulf Coast northward. In the extreme West the precipitation is least in the southern portion of the Pacific Coast region and increases steadily northward. The heaviest precipitation in any section of the country is that on the northern Pacific Coast. A great difference is also to be noted in the precipitation in different sections of the mountain districts. Much of the arid and semi-arid region between the eastern slope of the Rocky Mountains and the western coast ranges receives an annual average of less than 18 inches of rain, irrigation being necessary to bring crops to maturity. While the greatest precipitation at points east of the Rocky Mountains occurs during the warm months of the year, the reverse is true on the Pacific Coast. In fact, the precipitation is so light in summer and so pronounced in winter as to divide the year into two distinct seasons, one rainy and the other dry.

On account of the prevailing lake winds, the precipitation at Buffalo is greater than that at other points in the southern Lake Region, the annual average being 36.1 inches. Chicago's precipitation is 33.5 inches. The precipitation at New York, Boston and Washington may be considered typical of that of the eastern section of the United States, the amounts being 40.7 inches, 35.4 inches and 41.9 inches, respectively. The greatest rainfall in the South occurs at New Orleans, where 61.2 inches annually are recorded. At Chicago, the precipitation is less in winter than in summer, although the frequency is much greater in the colder months. This statement applies also to nearly all cities in this country and in Europe. The average annual number of days attended by precipitation at Chicago is 125, or about one day in three, but the actual number has varied greatly during the period of record. The largest number of days on which measurable precipitation occurred in any year was 166 in 1878, while the smallest number was 106 in 1895 and again in 1910.

The precipitation in Chicago is usually well distributed throughout the year. Rarely has a protracted drought been recorded. During the past 40 years, the longest period without precipitation of any kind was of 21 days' duration, covering the first three weeks of February, 1877. During the remainder of that month only 0.06 inches fell, making it the driest month of record in Chicago. Only 8 other periods of 15 days or more without precipitation have occurred since the establishment of the weather office at Chicago, and there have been 24 periods of 15 days or more in which not more than a "trace" of precipitation occurred. It is during such dry seasons that the burden of atmospheric dust increases to a maximum.

Cities located in regions of comparatively high humidity and subject to the contaminating effects of dust, smoke and their accompaniments, find relief intermittently through the agencies of wind or rain, or both. If the city of Chicago possessed distinct wet and dry seasons and if the latter were of comparatively long duration, the contaminating effects of dust and smoke would become more objectionable than at present; but the fact that Chicago's rainfall is usually well distributed throughout the year gives assurance of frequent elimination of impurities from the atmosphere. Heavy intermittent showers followed by much longer periods of sunshine materially contribute to a wholesome atmosphere.

113.07 Sunshine: The sunshine recorder employed by the Weather Bureau in the United States records the duration of sunshine only; it does not distinguish in any way between the varying intensities of the sun's rays. It is adjusted to record sunshine whenever the actual disc of the sun is visible, even though clouds may intercept a portion of the sun's rays. As a consequence, sunshine may be continuous when a thin stratum of cloud covers the entire sky. Sunshine is diminished in the daytime by clouds, fog, smoke, haze, and sometimes by a combination of two or more of these. In clear weather the smoke alone, it is thought, is never sufficient to prevent a record of sunshine. It does prevent such a record occasionally in connection with fog and doubtless, in some cases, with partial cloudiness when the sun would otherwise be visible.

Owing to differences in the recording instruments employed, the record for European cities is not comparable with that for cities in the United States, but with due allowance for these differences the record seems to indicate that the average percentage of sunshine is considerably less in Europe than in the United States. Chicago has an annual average of sunshine of 57.4 per cent. The Atlantic Coast cities, New York and Boston, have relatively high averages of sunshine, 61.3 per cent and 58.7 per cent, respectively. Cities farther south have lower averages, that for Philadelphia being 56.7 per cent and that for Washington 54.6 per cent. Pittsburgh with 49.0 per cent and Scranton with 38.4 per cent have the lowest values among cities in the Eastern States. These low percentages are due partly to the local smoke producing industries and partly to the fact that these cities are located within the paths, not only of the disturbances which cross the Great Lakes and the Ohio Valley, but also of those whose centers move northward along the Atlantic Coast.

Cities in the Plains States, such as St. Paul, Kansas City and Omaha, have higher averages than Chicago, their percentages being 60.6, 63.9 and 59.3, respectively. Denver, located in the foothills of the Rocky Mountains, has a still higher percentage. In general, the amount of sunshine increases from the Great Lakes westward to the Rocky Mountains, thence southwestward to the South Pacific Coast, Los Angeles with a percentage of 71.0 having the highest average. Passing northward along the Pacific Coast, the percentages diminish and reach a minimum at Seattle with 42.9 per cent. This low value is not only due to the persistent rainy weather during the colder months of the year, but also to considerable cloudiness during the summer months. Cities in the Gulf States, such as New Orleans and Birmingham, show about the same percentage as Chicago.

Chicago, with its annual average percentage of 57.4, enjoys a greater amount of sunshine than other cities in the southern Lake Region. The values for other lake cities are as follows: Cleveland, 50.6 per cent; Detroit, 49.3 per cent; Toledo, 52.6 per cent; and Buffalo, 49.5 per cent. The low values for Detroit and Buffalo are due to the persistency of cloudy weather accompanied by snow in the winter time. At Chicago, the highest monthly average is 71.0 per cent for July. The highest recorded average for any one month was 84.0 per cent in March, 1910, which was the warmest, driest, sunniest March covered by the records of the local weather bureau. The lowest monthly average is 41.0 per cent for December, and averages as low as 28 per cent were recorded in December, 1895 and 1896. At Buffalo, the percentages in the winter months often fall below 20, and in January, 1910, the low figure of 9 per cent was recorded.

At Chicago, during the summer season, a day with less than one hour of sunshine seldom occurs, and even in the winter months, when the mean duration of sunshine is less than 50 per cent of the possible amount, the days with one hour or more of sunshine average more than three in five. Because of the temperature conditions and the frequency of storms, cloudiness is, on the average, greater in winter than in summer. In the winter season, there may be several days in succession with skies so heavily clouded that no sunshine is recorded. The longest period of this sort on record for Chicago is one of 10 days from December 16 to 25, 1895. Another period of 9 days occurred from February 4 to 12, 1897. No long periods of the kind have occurred in the summer months; one of 4 days recorded in September, 1902, and another of 5 days in May, 1908, are the longest on record. Their occurrence has generally been confined to the months of November, December, January and February.

It occasionally happens that periods of settled weather, with continuous sunshine from sunrise to sunset, extend over several days. These periods are far more frequent in the early autumn than at any other time. They seldom occur in the summer because of the active convectional currents of warm afternoons, which usually give rise to clouds of the cumulus type, interrupting at intervals the rays of the sun. They are also very infrequent in winter because of prevailing conditions favorable to cloud formation. The two longest periods of continuous sunshine, 8 and 7 days in extent, respectively, occurred in the autumn.

The extent to which atmospheric dust and smoke diminish sunshine is not accurately known. It is evident, however, that smoke does not have any appreciable effect upon upper cloud formations unless the dust particles and smoke ascend directly to the upper strata, the elevations of which are from 5,000 to 10,000 feet. In the upper atmosphere there are always strong currents, and by the time the dust particles from the smoke of any city reach the upper cloud layer they must necessarily have been transported many miles. Dust particles permeate the upper atmosphere throughout the world and are in constant motion. Within six months after the eruption of Krakatoa, in the Straits of Sunda, the volcanic dust had encircled the globe, as was apparent from the haze which caused red sunsets for a long period. A similar haze was visible at Chicago after the eruption of Mount Pelee, May 8, 1902.

From the foregoing discussion, it is evident that dust particles present in the upper strata above Chicago may have been conveyed many miles, possibly from St. Louis, Kansas City, Denver, San Francisco, Honolulu or Tokio. Smoke arising from the furnaces of any city has no appreciable effect upon local cloud formations, but it is a most important factor in the formation of fog and thus operates to decrease the amount of sunshine. On the other hand, sunshine is a powerful factor in dispelling fogs, being at least of equal importance with wind in this respect. Sunshine, which might be considered nominally as the visible heat of the sun, operates by increasing the temperature of the atmosphere and thereby preventing the maximum degree of humidity necessary for the formation of fog.

113.08 Conclusions Regarding the Effects of Meteorological Phenomena upon Atmospheric Pollution: An analysis of the facts set forth in the preceding sections seems to justify certain conclusions with reference to the extent to which meteorological conditions serve to intensify or diminish the effects produced by smoke upon the atmosphere of Chicago. These may be summarized as follows:

1. Wind movement has the effect of dissipating the polluting constituents of the atmosphere and of rendering them less objectionable. The extent to which products of combustion are effective in polluting the atmosphere may be said to vary inversely as the velocity of the wind.

2. Wind velocities in Chicago are relatively high and, as a consequence, the observed effects produced by a given amount of smoke are less in Chicago than those which are produced by the same amount of smoke when discharged into the atmosphere of most other cities.

3. Temperature as a factor in atmospheric pollution is of indirect importance only; it exerts an influence upon other atmospheric conditions, such as wind and humidity, which are factors of great importance. This relationship between temperature and other conditions is, however, complex. Chicago's recorded temperature is a little higher than that of neighboring lake cities, but it is believed that the actual differences are not great.

4. High relative humidity serves directly to intensify the effects of atmospheric pollution in that it promotes the formation of fogs or mists which hold the products of combustion in the atmospheric strata near the earth. The records show that the humidity of Chicago's atmosphere as compared with that of other cities is of intermediate value.

5. Precipitation is an effective purifier of the atmosphere. It operates to wash out a large portion of the polluting substances suspended in the air. Few cities have a more favorable distribution of rainfall than that recorded for Chicago.

6. Sunshine, as a factor affecting atmospheric pollution, tends to diminish the effects of the polluting constituents of the air in that it produces a condition of low humidity. Few cities east of the Mississippi River surpass Chicago in percentage of sunshine.

7. Sunshine, as affected by atmospheric pollution, serves as an indirect measure of the extent of the pollution. Chicago's relatively high percentage of sunshine is evidence that its degree of atmospheric pollution is not greater than that of most other cities similarly located.

8. In general, the combination of meteorological conditions which tends to intensify the effects of polluting substances in the air includes low wind velocity, comparatively low temperature, high relative humidity and absence of sunshine.

9. Meteorological conditions tending to diminish the effects of polluting substances in the air include moderate or high wind velocities, high temperature, low relative humidity, intermittent showers and periods of sunshine.

10. Chicago's weather conditions, in their relation to the maintenance of a pure and wholesome state of the atmosphere, are far superior to those of most other cities of the United States and Europe.

11. In general, weather conditions in Chicago do not appear to operate so as to intensify the effects of atmospheric pollution. Periods for which the reverse is true are of brief duration.

THE ATMOSPHERE OF CITIES AS DESCRIBED IN SCIENTIFIC LITERATURE*

113.09 Atmospheric Air: The atmosphere of large cities is a complex mixture of numerous substances. The well known gaseous constituents normally found in the atmosphere of cities include oxygen, nitrogen, carbon dioxid and water vapor. Hydrocarbons, solid particles and compounds of nitrogen, chlorin, sulphur and carbon are also found in varying amounts. Rare gases such as argon, helium, neon, krypton and xenon are always present in the atmosphere in small quantities. Ozone also is often present. All of these rare gases except ozone are inactive and possess no marked characteristics. Atmospheric air has almost exactly the same composition throughout the world, yielding as a mean 21 per cent by volume of oxygen and 78 per cent by volume of nitrogen; the remaining 1.0 per cent consists of the rare gases mentioned. Divergences from the normal amount of oxygen in the air are often to be noted in closed rooms, in natural caves and in mines. The percentage of nitrogen in atmospheric air remains unchanged unless the amount of oxygen is changed or other gases are added. The proportion of carbon dioxid in atmospheric air varies somewhat with locality. Large amounts of this gas are sometimes emitted

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*A more elaborate review of the literature relating to atmospheric air is presented in chapter 101.

by volcanoes; deep springs are sometimes charged with it; all animal organisms secrete it; and the combustion of fuel produces it. The normal amount, according to Renk, is about .03 per cent or 3 parts in 10,000. Water vapor is always present in air and, as has been shown, it may have an important influence upon the effects of atmospheric pollution. Ammonia, nitric acid and nitrous acid are present in the atmosphere, usually only in very small amounts.

In addition to gases, atmospheric air contains an important dust content. It has been shown by experiment that dust is always present in the atmosphere even when the latter appears clear and pure. This atmospheric dust ordinarily comprises a variety of materials, including sand, salt, soot, cotton fiber, vegetable debris, bacteria, diatoms, monads, infusoria, pollen of flowers, straw and epithelial scales from the skin. The number of dust particles found in the atmosphere of country and mountain districts, where air is regarded as being in its purest state, varies from 200 to 10,000 particles per cubic centimeter. The volitant or traveling capacity of dust is an attribute of great importance. Some particles fall readily; some remain suspended in the air and may be transported long distances. Any dust nuisance originating in a local source may, therefore, affect the atmosphere of wide areas. The fact that dust forms a basis for mists, fogs and clouds is important, and the presence of fogs in various large cities has often been attributed to the dust particles contained in the products of combustion.

113.10 The Atmosphere of Cities: The atmosphere of cities differs from that of country districts in its content of positive atmospheric impurities, including dust and the solid and gaseous products of combustion. The presence of the solid products of combustion in any appreciable quantity may be said to be characteristic of city air. Sulphur dioxid and sulphur trioxid, rarely found in country air, are often important and very active constituents of city air. Carbon monoxid, which cannot be regarded as a constituent of country air, has been found in small quantities in city air. Other impurities such as ammonia, nitrous acid and nitric acid, are sometimes found in greater quantities in city air than in country air.

Upon the basis of the results of the studies and experiments of various investigators, air may be said to be polluted when the amount of the several impurities present exceeds that normally found in country air. The amount of such impurities necessary to render the air injurious to animal or vegetable life or to material objects, is a matter which has not been satisfactorily determined.

This statement of the nature of atmospheric air as described by the literature of the subject properly serves as an introduction to the analytical processes involved by the Committee's study of Chicago's atmosphere, an account of which follows.

COMPOSITION OF THE ATMOSPHERE OF CHICAGO AS DISCLOSED BY ANALYSES OF AIR SAMPLES*

113.11 Extent of the Investigation: The polluting constituents of the atmosphere of Chicago, as shown by preceding chapters of this report, have many sources of origin, such as the combustion of fuel, various industrial and commercial activities, building construction, processes incident to the repair of streets and sidewalks, the abrasive action of traffic and influences tending to disturb and redistribute deposits of dust. The polluting substances arising from these different activities vary in character and importance. The investigation of the Committee was undertaken for the purpose of obtaining data from which to define and measure the effect of each substance, and particularly to determine the extent to which products of combustion tend to pollute the atmosphere. The researches included chemical, physical and microscopical analyses of samples of air taken at numerous points throughout the Area of Investigation, from Lake Michigan on the east to La Grange on the west, and from Ravenswood on the north to South Chicago on the south. The atmosphere of the business districts particularly was made the subject of extensive studies. The samples of air of which analyses have been made were collected in districts near railroad lines, in industrial centers, near the buildings of manufacturing plants and in residential and park districts. All samples of air from which determinations have been made were taken near the street level.

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*A more complete record of the methods employed in the investigation here reported will be found in the Archives of the Committee, Vols. A 1 and A 2

During the period from May 20, 1912, to June 27, 1913, 154 tests were conducted in different parts of the city of Chicago and 6 additional tests were made at La Grange, Ill. These tests were classified according to the character of the district in which they were conducted, the following district classes being recognized:

1. Park.
2. Playground.
3. Residence.
4. Mixed Residence.
5. Industrial.
6. Boulevard.
7. Railroad.
8. Loop.

Tests included under the "Park" class embrace those made in or near the parks, including the grounds of the University of Chicago and the immediate neighborhood of Logan Square. A total of 24 park tests was made, 20 having been conducted during the day and 4 during the night.

Tests included under the "Playground" class embrace those made in the vicinity of playgrounds, which are frequently only small open spots in thickly populated districts. A total of 9 playground tests was made, 6 having been conducted during the day and 3 during the night.

Tests included under the "Residence" class embrace those made in neighborhoods in which the combustion of fuel was largely confined to domestic furnaces, and in which the more prolific sources of pollution, such as railroads, factories and power plants, were not numerous. A total of 33 residence tests was made, 24 having been conducted during the day and 9 during the night.

Tests included under the "Mixed Residence" class embrace those made in districts in which the influence of polluting factors other than domestic furnaces was noticeable. A total of 25 mixed residence tests was made, 20 having been conducted during the day and 5 during the night.

Tests included under the "Industrial" class embrace those made in warehouse districts, in neighborhoods in which were located a number of factories or in which some individual industrial plant was known to constitute an important source of atmospheric pollution. Tests made in the vicinity of the stockyards were included in this class. A total of 35 industrial tests was made, 26 having been conducted during the day and 9 during the night.

Tests included under the "Boulevard" class embrace those made on boulevards regardless of the immediate surroundings. Some of these tests have been included also under other classifications according to the character of the district in which the point of collection was located. A total of 20 boulevard tests was made, 15 having been conducted during the day and 5 during the night.

Tests included under the "Railroad" class embrace those made in the immediate vicinity of railroad lines. A total of 52 railroad tests was made, 38 having been conducted during the day and 14 during the night.

Tests included under the "Loop" class embrace those made in the downtown business district.* They also include a few tests made in localities immediately adjoining this district. A total of 33 loop tests was made, 26 having been conducted during the day and 7 during the night.

In many cases, a day and a night test were conducted near the same point in order to determine the effect of the difference in traffic and other activities. Some night tests were conducted at points at which no day test was undertaken, but in such instances a comparison between day and night results has been made by considering the night results in connection with the results of a day test made at a point similarly located.

In order to compare conditions in the city with those at points where less atmospheric pollution might be expected, 6 tests were conducted at La Grange, Ill., a town with a population of about 5,000, located 12 miles west of the Chicago City Hall, near the western boundary of Zone B. Few industries are located in La Grange, although two railroads pass through it.

The locations of the points at which collections of air samples were made are indicated by the map which is presented as fig. 67.

113.12 Methods Employed: In the methods employed in this investigation for determining the chemical and physical properties of the polluting constituents of the atmosphere the Committee has aimed at simplicity, accuracy and reliability. At the outset it was recognized as desirable that the apparatus, as well as the methods employed, should involve no complicated manipulations

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* The district bounded by Lake Street on the north, Wabash Avenue on the east, Van Buren Street on the south and Fifth Avenue on the west is commonly called the "Loop." It derives its name from the fact that the elevated railways of Chicago have elevated structures in the streets named upon which the return loop of all lines was originally made.

The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals
Office of Chief Engineer Chicago, 1914

FIG. 67. POINTS AT WHICH AIR SAMPLES WERE COLLECTED FOR ANALYSIS. TEST NUMBERS ARE SHOWN FOR EACH LOCATION

which might introduce error or decrease the facility with which the work might be carried on. This was necessary in order to insure results directly comparable in all instances.

Descriptions of investigations previously conducted present some inconsistencies and inaccuracies in nomenclature, and difficulty has been experienced in readily understanding the values presented in the printed reports. For instance, the gaseous sulphur compounds, or acid radicals containing sulphur, such as sulphur trioxid (SO_3) and sulphur dioxid (SO_2), are frequently referred to as sulphuric acid and sulphurous acid, respectively, although neither possesses acid properties. These compounds remain in the form of oxids only under special conditions and it is difficult to determine which of them is meant when the terms sulphuric acid and sulphurous acid are employed, or, for purposes of comparison, to convert the values given to more definite units of measure. The gas, carbon dioxid, which is a product of combustion and of animal respiration, is often referred to as carbonic acid while, in fact, its solution only is an acid.

In recent years chemical nomenclature has been very generally standardized, so that it is now possible to designate substances with scientific accuracy.

In order to eliminate the possibility of any misinterpretation of the results presented in this report, the correct chemical name of each substance considered and its corresponding formula are given in the following:

CHEMICAL NAME	FORMULA	UNIT OF MEASURE EMPLOYED
Oxygen	O	Not determined
Nitrogen	N	Not determined
Carbon dioxid (carbonic acid)	CO_2	Parts CO_2 per 10,000 of air
Ozone and other rare gases		Not determined
Carbon monoxid (carbonic oxid)	CO	Not determined
Ammonia	NH_3	Milligrams of NH_3 per cubic meter of air
Nitrous acid, nitrites	HNO_2	Milligrams of HNO_2 per cubic meter of air
Nitric acid, nitrates	HNO_3	Not determined
Chlorin, chlorid	Cl	Milligrams of Cl per cubic meter of air
Sulphur	S	Milligrams of H_2SO_4 per cubic meter of air
Sulphur dioxid	SO_2	
Sulphurous acid	H_2SO_3	
Hydrogen sulphid	H_2S	
Sulphur trioxid	SO_3	
Sulphuric acid	H_2SO_4	
Material collected in filter; mineral matter, soot, cinders, dirt, street debris, etc.		Milligrams of solids per cubic meter of air

After a study of results of previous investigations, it was decided to adopt as a uniform volume for test samples 30 cubic meters, or about 1,000 cubic feet, of air. It was expected that a sample of this volume would ordinarily contain sufficient quantities of the various polluting substances to indicate their extent accurately. It was estimated that a period of six or seven hours would be required to pass a sample of air of this volume through the sampling apparatus. The problem of collecting such a sample and transporting it to the laboratory for analysis presented many difficulties, and the most satisfactory solution seemed to lie in the construction of a portable laboratory which might be operated at any desired point. A special laboratory installed upon a motor chassis was accordingly built for the purpose (figs. 76 and 77, section 113.14).

Practically all analytical methods of investigating the atmosphere depend upon the absorption of polluting constituents by suitable solutions. It is possible to select separate solutions for many substances, but this process would be impracticable and complex in its operation. Therefore, it was decided that the use of an acid and an alkaline solution as absorbents would yield sufficiently accurate data for a comparison of conditions in various locations. The absorption apparatus and the solutions used are hereinafter described.

Because of the relatively large proportion of carbon dioxid in the air, the complete removal of this constituent by absorption from all the air passing through the apparatus was not attempted. The determinations of carbon dioxid were made by the Pettenkofer method, which is commonly used in connection with samples of 4 to 5 liters. This method requires the following solutions:

1. A standard solution of hydrochloric acid.
2. An approximately tenth-normal solution of hydrochloric acid.
3. An approximately tenth-normal solution of barium hydroxid.
4. A solution of phenolphthalein.

The standard solution was accurately standardized according to methods commonly used. One cubic centimeter of this acid was equivalent to 0.25 cubic centimeters of dry carbon dioxid under standard conditions, that is, at 0 degrees centigrade and 760 millimeters (mercury) barometric pressure.

The tenth-normal solutions were so prepared that 50 cubic centimeters of the barium hydroxid required 50 cubic centimeters of the acid, and in addition, 15 to 20 cubic centimeters of the standard hydrochloric acid, to neutralize it, using phenolphthalein indicator.

The tenth-normal hydrochloric acid solution was made by adding hydrochloric acid (specific gravity 1.20) to distilled water in the proportion of 8 or 9 cubic centimeters of acid to one liter of water.

FIG. 68. APPARATUS EMPLOYED FOR CARBON DIOXID DETERMINATIONS

The barium hydroxid solution was made by dissolving 6.57 grams of the moisture-free salt $Ba(OH)_2$ in water and diluting the volume to one liter. The indicator phenolphthalein was made by dissolving one gram of the solid in one liter of ethyl alcohol.

An illustration of the apparatus employed for the carbon dioxid determinations is presented as fig. 68.

The bottles shown are common laboratory utensils, such as are ordinarily employed for handling acids. When the apparatus was prepared for conducting a test, bottle No. 1, which was fitted with a burette and atomizer tube with double valve, contained the standard hydrochloric acid, and bottle No. 3, which was equipped with a pipette of approximately 50 cubic centimeters capacity and means for transferring a quantity of the solution into the pipette, contained the tenth-normal hydrochloric acid solution. The guard tube on bottle No. 3 contained water which served as a trap to prevent the pipette from drying out when not filled with solution. Bottle No. 4 contained a quantity of the tenth-normal barium hydroxid solution. In the connection to the atomizer bulb shown was placed a soda lime tube, and attached to the end of the pipette was a U-tube containing caustic soda. The solution in the U-tube acted as a trap to remove the carbon dioxid from the air entering the pipette. This not only preserved the strength of the solution, but prevented a precipitate of barium carbonate from depositing on the sides of the pipette and obscuring the surface line of the solution from view. Bottle No. 2 contained the indicator phenolphthalein.

The flasks shown in the upper portion of the illustration were used in the processes of collecting and analyzing the samples of air. The two at the right are shown as connected together in the manner employed during the collection of a sample. On the flask shown at the left is illustrated the method employed to close the flask during agitation, that is, during the time required for completion of the reaction between the barium hydroxid and the carbon dioxid in the air.

The procedure of analysis after the flasks containing the samples were removed from the series of flasks (fig. 68), was as follows: The barium hydroxid pipette on bottle No. 4 was filled to a point just above the mark on the upper stem and the level adjusted to the mark by allowing a few drops to flow from the tip. The adhering drop was carefully removed from the tip. The flask was then held near the pipette, the stopper from the top of the connection was removed and the tip of the pipette was inserted in the connection. The barium hydroxid was allowed to flow into the flask, care being taken to stop the flow when the level of the liquid had reached the mark on the lower stem and the last drop had fallen into the flask without touching the tip of the pipette to the connection. During a period of 90 minutes following, the flask was frequently agitated so that the barium hydroxid came into contact with all of the air. This was accomplished by shaking the flask with a rotary motion, so that the entire inside surface of the vessel became moistened with the alkali. Care was taken to prevent the barium hydroxid from coming in contact with the connection or with the neck of the flask. At the end of the period of agitation, the acid pipette, bottle No. 3, was filled to the mark, the same precaution being observed as in the case of the filling of the barium hydroxid pipette. The acid was then allowed to flow into the flask until the proper quantity had been admitted, and one drop of the indicator was added. The excess alkali was titrated with the standard acid, the titration being complete at the moment the solution lost its pink tint. The amount of standard acid used is called the "titration." The neck and connection of the flask were then rinsed with distilled water, the water used for this purpose being tested carefully for carbon dioxid and neutralized, if necessary, with barium hydroxid before using. Usually, distilled water is practically free from dissolved carbon dioxid; consequently, if only a small quantity of water is used, the result of the titration is not materially changed.

Once or twice a day, a blank test was performed as follows: Into a 250-cubic centimeter Erlenmeyer flask was introduced a quantity of acid corresponding to that used in the determination, and a quantity of barium hydroxid corresponding to that introduced into the flask was placed in the acid. The excess of alkali, after the addition of a drop of phenolphthalein, was titrated with the standard acid, thereby giving the "blank," or the difference between the barium hydroxid solution and the acid solution, in terms of the standard acid. The volume of this was at least 12 cubic centimeters. The blank was varied slightly, as desired in different determinations, by varying the quantities of alkali or acid solutions introduced. The process of making the blank determination by adding the alkali to the acid is preferable to the reverse procedure because the carbon dioxid in the air of the flask might easily change the value of the alkali while adding the acid to it. The total alkalinity was desired since it was used in the determination. The difference between the blank and the titration indicated the amount of standard acid equivalent to the carbon dioxid contained in the sample of air.

In the reaction which takes place between barium hydroxid and carbon dioxid,

$$Ba\ (OH)_2 + CO_2 = Ba\ CO_3 + H_2O,$$

the barium carbonate is precipitated and exerts no further influence upon the reaction. The formation of water also tends to carry the reaction to completion. It is known, of course, that barium carbonate in solution is not attacked by weak acids, but in the dry state it may be dissolved by them. The inside surfaces of the flask became coated with a mixture of barium carbonate and barium sulphate, but this did not appear to affect the reaction if the acid was not permitted to come in contact with the coating before reaching the solution. In fact, this condition appeared to be essential to correct results. It was noted that, when the flask was first washed with water, then with a little barium hydroxid and again with water, and allowed to drain, the most reliable results were obtained. In ordinary use, the flasks are merely rinsed carefully with water and allowed to drain.

All carbon dioxid determinations were made in duplicate. As a rule, the two results checked within one-hundredth of one per cent, or one-tenth part of carbon dioxid per 10,000 of air. Occasionally, when a greater variation was observed, the condition was no doubt attributable to the fact that the carbon dioxid contained in the air was changing at the time and the air samples employed in the two determinations were accordingly not of the same composition.

In the determinations for ammonia, four chemical solutions, besides distilled water and litmus paper, were required. The solutions were:

1. Strong standard ammonium chlorid.
2. Dilute standard ammonium chlorid.
3. Nessler reagent indicator.
4. Sodium hydroxid.

The strong solution of standard ammonium chlorid was so made that each liter contained one gram of nitrogen as ammonia. The dilute standard solution was prepared from this by diluting 10 cubic centimeters to one liter. The strong ammonium chlorid was prepared and checked, using the apparatus shown in fig. 69.*

The procedure for making the determination was as follows: An amount of the acid varying from 25 to 50 cubic centimeters, depending upon the amount of ammonia to be determined, was poured from the first acid flask into Nessler tube No. 1. Into Nessler tube No. 2 was poured a volume of 50 cubic centimeters of acid from the second acid flask and into each of the Nessler tubes, Nos. 3 and 4, was poured a volume of 50 cubic centimeters of the acid remaining after having filled the flasks before starting the test. To the contents of Nessler tube No. 4 was also added a volume of 2.5 cubic centimeters of the dilute standard ammonium chlorid solution. In Nessler tube No. 5 was placed a volume of 100 cubic centimeters of water for use in diluting the solutions, and in Nessler tube No. 6 was placed a volume of 5 cubic centimeters of the dilute ammonium chlorid standard solution diluted with water to make a total volume of 100 cubic centimeters. All of the acid solutions were neutralized with a caustic soda solution, litmus paper being used as the indicator. The contents of each of the Nessler tubes were then diluted to a volume of 100 cubic centimeters and one cubic centimeter of the Nessler reagent was added to each tube. The colors developed almost instantly.

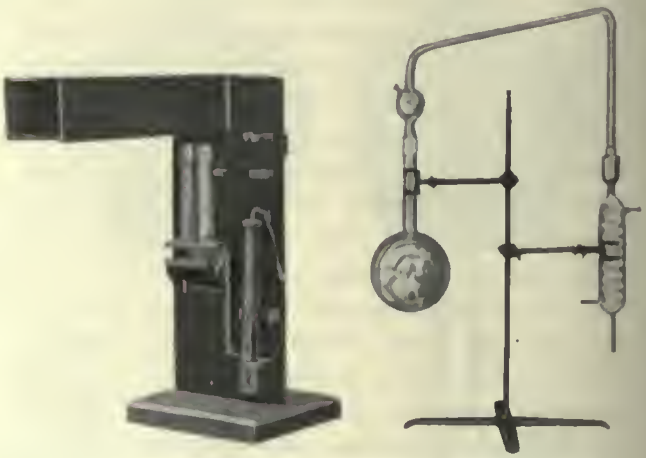

FIG. 69. TINTOMETER AND APPARATUS USED FOR DISTILLING AMMONIA

The contents of Nessler tube No. 6 were placed in the reservoir of the tintometer, shown as one of the units of apparatus illustrated as fig. 69.

The contents of the remaining Nessler tubes were introduced in turn into the comparing cylinder shown in fig. 69 at the left of the tintometer. By blowing air into the reservoir tube, the level of the solution in the comparing cylinder, which was connected to the reservoir tube, was changed until the depth of the yellow color of the solution in the left comparing tube was properly matched. The heights of the liquid in the two tubes varied inversely as the strength of the solutions. The height was measured by division marks etched on the tube, the distance between consecutive marks being equivalent to one-hundredth part of the total depth.

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* This apparatus is fully described in the Archives of the Committee, Vol. A 2.

The object of using two tubes containing ammonium chlorid standard solution was to insure correct manipulation of the apparatus and correct development of the colors, and also to check the sensitiveness of the reading of the colors. The amount of nitrogen, as ammonia, found in the blank, Nessler tube No. 3, usually 4 to 8 divisions, was subtracted from the amount found in Nessler tube No. 2. This amount of nitrogen in the blank was not, however, subtracted from that found in tube No. 1 unless the quantity was found to be below 25 divisions, for the reason that, when the color was about 25 divisions, the denser color masked the slight coloration of the blank. Thus, if the blank should show a reading of 8 divisions, the half-standard tube No. 4 should indicate 58 divisions, but in all probability it would read 50 or 52 divisions. Even in ammonia-free water, to which the reagent was added, a few hundredths of the standard solution was required to match the depth of color which could not be attributed to the presence of ammonia. The absence of color in tube No. 2 indicated that the absorption was practically complete in the first acid flask through which the air passed. Tests made of the alkali in the first flask, preceding the first acid flask, revealed no trace of ammonia. A turbidity which was not due to the precipitation of the reagent by an excess of ammonia often developed. These comparisons were therefore made before the turbidity developed. This required, at times, the preparation of new solutions. The temperature of the solutions at the time the Nessler reagent was added was found to be unimportant, because the colors developed quickly at all times and the half-standard checked with the standard made in water solutions. The process of diluting the colors after the addition of the reagent was not found an accurate method of comparison and was therefore not used in the investigation. If the color was too deep, a new solution was made by using a smaller quantity of acid.

For the analysis of rain or snow water, the procedure was practically the same, except that the water was not neutralized before the addition of the Nessler reagent. The quantity of water tested depended upon the amount of ammonia present, and therefore more than one sample was sometimes required. The color of the sample was compared with the standard used for the other solutions.

In the process of determining nitrous acid, or nitrogen in the form of nitrites, the materials required were as follows:

1. A strong standard sodium nitrite solution.
2. A dilute standard sodium nitrite solution.
3. Sulphanilic acid.
4. Alpha-amidonaphthalene acetate.
5. Acetic acid.
6. Hydrochloric acid.
7. Water free from nitrites.
8. Litmus paper.

It is unnecessary, for the purposes of this report, to describe the preparation of these solutions since such description would be of interest only to a chemist desiring to repeat the work. It is sufficient to state that the dilute standard sodium nitrite solution contained 0.001 milligrams of nitrogen as nitrite.[*]

While the general procedure employed in this determination was similar to that employed in the determination of ammonia, there were some points of difference. The solutions placed in the Nessler tubes were as follows:

In tube No. 1, 25 cubic centimeters of solution from alkaline flask No. 1, first in the series.
In tube No. 2, 50 cubic centimeters of solution from alkaline flask No. 2, fourth in the series.
In tube No. 3, 50 cubic centimeters of solution from alkaline flask No. 3, fifth in the series.
In tube No. 4, 50 cubic centimeters of solution from alkaline flask No. 4, sixth in the series.
In tube No. 5, 50 cubic centimeters of the alkali remaining after filling the flasks for the test.
In tube No. 6, 50 cubic centimeters of the alkali remaining after filling the flasks plus 2.5 cubic centimeters of dilute standard sodium nitrite solution.
In tube No. 7, 5 cubic centimeters of dilute standard sodium nitrite solution diluted with water to 50 cubic centimeters.

All of the alkaline solutions were neutralized with acetic acid, litmus paper being used as the indicator. The neutralization was usually completed before the evolution of carbon dioxid ceased. All of the alkaline solutions, after being acidified, were diluted with water to about 90 cubic centimeters. The contents of tube No. 7, the standard solution, were diluted to 96 cubic centimeters.

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[*] The preparation of these solutions is fully described in the Archives of the Committee, Vol. A 2.

After adding two cubic centimeters of each of the indicators to each tube and thoroughly mixing, the tubes were allowed to stand for a few minutes, after which the pink color usually began to develop if nitrite was present. About 20 minutes later, 5 cubic centimeters of concentrated hydrochloric acid were added to each solution except that contained in tube No. 7. After the colors developed, the comparison was made by means of the tintometer as in the ammonia determination. The use of hot water for diluting the solutions was found to hasten the action and to produce better results than cold water. Although too great a quantity of acid would probably cause the color to fade after a time, it was often found necessary when making the color determination to increase the amount of hydrochloric acid used, in order to change the tint from a brick red color to the brilliant pink of the standard. The fact that the half-standard solution contained in tube No. 6 invariably checked, showed that the addition of hydrochloric acid did not result in the production of a color more pronounced than the nitrite present should show. The development of the proper shade was accelerated when the hydrochloric acid was added after the color showed quite strongly. It was found impossible to match different shades of color correctly for intensity. Agitation of the solutions was found important. The matching of colors was made more accurate when the color was not too deep or such that the standard solution filled the tube to a point between 25 and 60 divisions. When the color was deeper, that is, above 60 divisions, it was considered preferable to dilute the solution and make a comparison of the lighter shades. The reagent blank, or the reading obtained from tube No. 5, was subtracted from the others when the colors were low; otherwise, the faint color found was obscured by the strongest color. The difference between the height of the tint in tube No. 6, measured in divisions and 50, was found to be a safe guide to the correction made for nitrite in the reagents. Often considerable nitrite was found in the reagents.

For the determinations of nitrite in rain and snow the procedure was the same as that described except that the neutralization was omitted. The sample of 25 or 50 cubic centimeters was diluted with hot water and the reagents then added. The addition of hydrochloric acid was not usually required.

In the determinations for chlorin the following solutions were required:*

1. Silver nitrate.
2. Potassium chromate.
3. Strong standard sodium chlorid solution.
4. Dilute standard sodium chlorid solution.
5. Sulphuric acid.
6. Phenolphthalein.

The apparatus needed for the chlorin determinations included the following:

1. Two 4-inch porcelain evaporating dishes.
2. Two short stirring rods of glass tubing.
3. A 50 c.c. burette for measuring silver nitrate.
4. A 1 c.c. pipette for measuring the indicator.
5. A 5 c.c. volumetric pipette for measuring the standard chlorid.
6. A 25 c.c. volumetric pipette for measuring the solutions.
7. A 25 c.c. volumetric pipette for use with sulphuric acid.
8. Phenolphthalein bottle with dropper.

The procedure was as follows: A volume of 25 cubic centimeters of the alkali remaining after the flasks had been filled, was placed in an evaporating dish and 25 cubic centimeters of the solution from flask No. 1 were poured into a second evaporating dish; 5 cubic centimeters of the dilute sodium chlorid solution were then added to the contents of each dish. After adding a drop of phenolphthalein, the solutions were neutralized with dilute sulphuric acid from a pipette. One cubic centimeter of the potassium chromate indicator was added to each solution and the solutions were titrated with the silver nitrate until a red color appeared. The completion of the titration was easily recognizable after several experiments. The difference between the amount of silver nitrate required for the 25 cubic centimeters of solution from the first flask and that required for the 25 cubic centimeters of the stock solution gave the silver nitrate equivalent to the chlorin in the sample from the first flask. Care was taken to avoid making the solutions acid, since even slightly acid solutions were found to change the color of the indicator to a reddish yellow, and to render the completion of the titration difficult to detect. This procedure

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* The preparation of these solutions is described in the Archives of the Committee, Vol. A 2.

permitted a standardization of the silver nitrate in every determination and also gave an accurate basis of comparison between the blank or standard titration and the titration of the solution from the first flask.

The process of determining the chlorin in rain and snow differed slightly in detail only. Distilled water, instead of alkali, was used for the standardization of the silver nitrate and for color comparison.

The well known gravimetric method of determining sulphur was used, the analyses being made in the laboratory instead of in the automobile.[*]

While it has sometimes been stated that an alkaline solution does not completely absorb the sulphur compounds of the air, the results of this investigation show that the absorption is practically complete. A number of determinations for sulphur both in the first acid solution and in the second alkaline solution were made. In the acid, as would be expected, no traces of sulphur were found. In the second alkaline solution, sulphur was usually found in amounts of from one to two milligrams, regardless of the amount in the first alkaline flask. For instance, when the sample from the first flask showed 30.5 milligrams of barium sulphate, that in the second flask showed only 2.8 milligrams. Various tests of the alkali itself always yielded a blank of at least one milligram.

Allowance for this blank was not made, nor was the small amount of sulphur found in the second alkaline solution considered, so that these two small errors balanced and all results are comparable.

Determinations for solids in the atmosphere were made by a process of filtering in which filters cut down from extraction thimbles to measure 100 millimeters in length and 80 millimeters in diameter were used. Each filter was first filled with cotton and then placed in an oven regulated automatically to maintain a temperature of 107 degrees centigrade. The filter remained in the oven for about one week, after which, on successive days, it was weighed until there was found to be a difference of not more than one milligram in its weight at two successive weighings. In this process of weighing considerable care was exercised. The filter, after being removed from the oven, was placed in a glass stoppered weighing bottle which was deposited in a desiccator for a period of 30 seconds. The bottle and filter were then weighed as quickly as possible, the bottle having a counterpoise. The filter was returned to the desiccator and the bottle was replaced on the weighing pan. The difference between the weight of the counterpoise and that of the bottle was recorded as being due to the collection of moisture on the bottle. The two weighings gave the actual weight of the filter, which usually approximated two grams. This process was repeated after the filter had been used in a test. Following the final weighing the filters were preserved for microscopical examination, in which the contents were identified in as much detail as possible.

Atmospheric conditions which prevailed when the samples were being collected, such as the direction and velocity of the wind, temperature, humidity and barometric pressure, were taken into consideration in order to make accurate comparisons and calculations.

During a test the pressure measured at the meter was always less than atmospheric pressure, a circumstance due to the effect of the mechanical exhaustion of air from the apparatus by the pump. This difference was measured at one-hour intervals by means of a manometer connected to the meter inlet, the difference in the height of the two columns of mercury in the manometer constituting a measure of the vacuum produced by the pump or, inversely, of the pressure required to force air through the apparatus. The temperature of the air in the meter inlet was recorded hourly as indicated by a centigrade thermometer.

Relative humidity and aqueous pressure during the period of collection of each sample were determined from the readings of the dry and wet bulb Fahrenheit thermometers, the aqueous pressure being necessary in the calculation of the carbon dioxid ratio. The two thermometers, when used together in the form of a sling psychrometer, were whirled in the air until the wet bulb thermometer recorded a minimum or constant value. From the data obtained in this manner, the values for relative humidity and aqueous pressure were obtained from standard tables. These readings were taken at one-hour intervals.

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[*] Details relating to this method are given in the Archives of the Committee, Vol. A 2.

Since the wind may be deflected by buildings and other structures, its direction as observed at the point of collection may not have been, in all cases, the prevailing direction over the surrounding territory. The direction, as recorded for a test, was usually determined by observing the direction indicated by smoke emissions or flags apparent from the point of collection. At times, this method proved unsatisfactory, especially in the case of very low wind velocities. In order that the record of wind direction might be uniform, the prevailing direction, as observed by the Chicago weather bureau, was used in all tabulated data. The wind velocity at the street level was observed at intervals of one hour, by means of an anenometer, except during periods of precipitation and periods when the wind velocity was so low that the anemometer revealed practically no movement during one minute.

The calculations for the reduction of the volume of air measured by the meter, to standard conditions are familiar to all those concerned with such reductions.*

113.13 Polluting Constituents of the Atmosphere as Disclosed by Rain and Snow Analyses: During the period covered by this report, 18 samples of rain were collected on different dates and at various points, and 21 samples of snow were taken simultaneously at various locations. The samples of rain were collected by means of a galvanized iron pan placed on top of the automobile laboratory and connected by a drain with a bottle on the inside of the laboratory. The analyses were made by processes which have been hereinbefore described. While results obtained from these tests are not regarded as significant or as comparable in any way with the results of the air analyses, they provide a basis upon which comparison may be made with results of investigations elsewhere. The results of the rain analyses are presented as table CXII.

A study of these results shows that high values for one or more substances were obtained from the samples of rain collected in the vicinity of different industrial activities, but there appeared to be no regular rate of decrease, such as might be expected, in the amount of impurities detected as the distance of the point of test from the centers of these activities increased. In test No. 132, conducted in a railroad yard, the amounts of all impurities detected were considerably larger than the averages. In test No. 126, conducted at a point north of the stock yards, the values for ammonia and sulphuric acid were high. In test No. 23, conducted at a point in a manufacturing and warehouse district, the values for all substances, except chlorin, were above the averages. Test No. 136, conducted at a point beyond the city limits, presented exceptionally low values for all substances. In test No. 64, which was conducted on a foggy day in the neighborhood of a railroad roundhouse, the effects of the intense degree of local pollution and of the atmospheric conditions were emphasized by the high values obtained for all substances except ammonia.

The influence of temperature upon the degree of pollution was not made apparent by these results, since only 4 of the samples were collected during the winter months and only 6 at a temperature of less than 50 degrees. The results

TABLE CXII. RESULTS OF RAIN ANALYSES—MILLIGRAMS PER LITER OR PARTS PER MILLION

Test No.	Location	Date	Wind Dir.	Temp. Deg. F	Nitrous Acid	Ammonia	Chlorin	Sulphuric Acid
1	2	3	4	5	6	7	8	9
10	Ohio and Peoria Sts.	6-13-12	NE	62	0.0838	2.187	.....	32.4
11	Ohio and Peoria Sts.	6-14-12	E	65	0.0838	0.280	.....	95.0
20	90th St. and Muskegon Ave.	7-9-12	SW-S	84	0.0838	0.000	17.50	36.5
23	Washington Blvd. and Desplaines St.	7-13-12	SW	75	0.2513	1.580	0.00	189.0
27	Vedder and Penn Sts.	7-20-12	SE	64	0.1175	0.912	18.00	67.2
42A	Washington Blvd. and Talman Ave.	8-19-12	SW	70	0.2345	0.243	1.92	67.7
42B	29th St. west of Halsted St.	8-20-12	SW-W	72	0.2076	0.730	0.00	.....
64	Chicago Ave. and Halsted St.	10-31-12	NE	44	0.3216	0.532	18.18	845.0
67	School St. and Elston Ave.	11-6-12	N	47	0.0804	0.484	0.00	52.1
85	47th St. near Center.	1-20-13	NW	24	0.2010	0.968	3.00	21.0
99	Dearhorn St. north of Adams St.	2-21-13	NE-E	34	0.7370	0.218	36.70	428.1
116	Michigan Ave and Congress St.	4-9-13	E	40	0.0402	2.056	7.77	108.2
122	Canal St. south of Randolph St.	4-25-13	NW-N	46	0.2345	0.605	0.00	49.4
126	Emerald Ave. and 39th St.	5-5-13	S	70	0.1005	1.936	0.00	205.8
132	Federal and Taylor Sts.	5-13-13	NE-E	55	0.2680	1.936	15.70	198.4
136	5th Ave. and 47th St., La Grange.	5-20-13	W-SW	62	0.0670	0.303	0.00	22.5
156	Clark St. south of Adams St.	8-21-13	N	62	0.1005	0.774	5.82	28.8
...	1224 South Michigan Ave.	5-26-13	......	..	0.1440	0.532	5.88	4.5
Averages					0.1865	0.905	8.15	144.2

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*All methods of calculation employed in this investigation for computing the amounts of the various substances in the air sampled, are fully described in the Archives of the Committee, Vol. A 2.

of a few tests seemed to indicate that the content of sulphuric acid increases with temperature, but, on the whole, a high sulphuric acid content of a very limited number of samples cannot be assumed to point to a uniform rule.

The effect of wind direction was particularly noticeable in one case in which, under an east wind, a test conducted at a point near the lake front yielded a very low nitrite value. In fact, three tests conducted near the lake front, with an east wind, yielded lower nitrite values than were obtained in other tests. Samples collected at points near the city limits at periods when the wind was blowing toward the city yielded lower nitrite values than samples collected at similar points under a wind blowing from the city.

A definite relation between the different substances does not seem to be apparent from the results of the rain analyses. In general, the results of rain analyses serve to show that rain constitutes an efficient purifier of the atmosphere, since it collects and deposits upon the ground an appreciable amount of the polluting substances of the atmosphere.

The samples of snow analyzed were collected on March 1, 1913. A snow-storm of several days' duration began on February 25. By February 27, 4.5 inches of snow had fallen. On the 27th, the temperature rose sufficiently to cause the snow to thaw slightly, but on the 28th, the temperature fell and the snow on the ground was increased by additional precipitation. On March 1, when there was a fresh deposit of snow on the crust of the old snow, 21 samples of the fresh snow were collected at various points throughout the city. These samples were packed carefully in bottles, precaution being exercised to prevent the introduction of any foreign substances, and were taken to the laboratory for analysis. As a rule, only fresh snow on top of the crust was taken, but the varying depth of this layer of fresh snow required that a greater area be removed in some cases than in others. At certain points, even the fresh snow was found to have a crust. In one case a sample of old snow was collected after removing some of the crust, the wind having blown off all the fresh snow. One sample, consisting also of old snow, was collected on the morning of March 3 from the roof of the Harris Trust Building. After the samples had been allowed to melt in the laboratory, it was noted that certain particles had settled to the bottom and that a scum had formed on the top of the water resulting from the melted snow. The water was dark in color, except in the case of samples from the parks, which were almost clear. A portion of the liquid was carefully siphoned off and the remainder was filtered to remove the solid materials. The filtrate was used in the determination of sulphuric acid and the portion siphoned off was analyzed for the other substances. The solids were weighed and then subjected to physical classification and chemical analysis.

The methods employed in the analysis of snow samples for the determination of sulphuric acid, nitrous acid, ammonia and chlorin, were the same as those used for similar determinations in the analysis of rain water samples. Filtration was regarded as necessary, in connection with the sulphuric acid determinations, in order to remove any solid matter, especially sand, from the sample, this precaution being taken to avoid the possibility of weighing such substances finally as barium sulphate. On the other hand, the portion of the sample siphoned off was used in the determinations for other substances, in order to avoid the possible influence upon results of the presence of any soluble salts in the filter paper.

The solid matter removed by the process of filtering was, after being dried, subjected to a screening test by which those particles remaining upon a 20-mesh screen (400 apertures per square inch) were classed as coarse cinders, those passing through the 20-mesh screen but remaining upon a 200-mesh screen (40,000 apertures per square inch) were classed as fine cinders, and those passing through the 200-mesh screen were classed as dust. After separation in this manner, each class of material was weighed and the portions were again mixed in preparation for chemical analysis.

For the determination of tar, a half-gram sample of the solid materials was placed in the extraction shell of the Soxhlet apparatus and was extracted for two days, a reflux-condenser being used. The ether was then evaporated and the residuum of tar weighed.

For the determination of sulphur, a portion of the sample of solid materials was mixed with two and one-half times its weight of Eschka mixture (two parts sodium carbonate plus one part magnesium oxid). This mixture was fused in a platinum crucible, and the mass was then extracted with water and filtered. The filtrate was treated with bromine water and acidified, after which the barium sulphate was precipitated with barium chlorid, as previously described in connection with the method for determining sulphuric acid in solution (section 105.30).

For the determination of the ash content of the solids, a part of the sample was placed in a porcelain crucible and heated in a muffle to a temperature of 800 to 900 degrees centigrade, at which temperature the carbonaceous material was burned off, leaving the ash.

The results of the analyses of snow samples have been tabulated and are given as tables CXIII and CXIV. The values expressed in the column headed "Volume of Water, Liters" indicate the volume of water formed by the melted snow sample. The values appearing under "Composition of Solid Matter" are expressed in percentage by weight of the total solids. The letters "ND" indicate a sample insufficient to warrant the determination.

TABLE CXIII. LOCATIONS OF POINTS OF COLLECTION AND RESULTS OF MICROSCOPICAL EXAMINATIONS OF SNOW SAMPLES COLLECTED WITHIN THE AREA OF INVESTIGATION

Test					Snow Removed			Microscopical Examination	Test No.
No.	Date	Time of Collection	Location		Area		Vol. of Water Liters		
			Zone		In.	Sq. Meters			
1	2	3	4	5	6	7	8	9	10
1	3-1-13	A.M. 8:00	(A)	Jackson Park, on lake front; near road opposite pier in yacht harbor.	15x50	0.4839	1.215	Very few cinders; practically all clean sand; few fibers; one bit of wood	1
2	"	8:25	"	64th and Kimbark; in yard in rear of church.	15x45	0.4355	1.325	Fine cinders and ash; coal; charcoal; animal hair; a few spheres: mineral and other debris.	2
3	"	8:45	"	Washington Park; north end; open space.	15x45	0.4355	1.220	Minute fused spheres of ash: mineral debris; little sand, cinders; ashes.	3
4	"	9:00	"	Princeton and 47th; rear of school yard.	15x53	0.5129	1.370	Cinders; ash; a few spheres; sand; woody and other fibers; animal hair.	4
5-6	"	9:20	"	47th and Aberdeen; south of Hammond Packing Plant and Belt Ry. tracks.	15x67	0.6484	1.365	Cinders and ashes.	5-6
7	"	9:45	"	45th and Marshfield; Davis Square Playground	15x60	0.5807	1.350	Cinders; ash; a few ash spheres; fibers	7
8	"	10:15	"	29th and Poplar; Mark White Playground.	15x60	0.5807	1.350	Cinders; ashes; some fused spherical ash bodies.	8
9	"	10:45	"	Loomis off 22d; Lumber yards.	15x70	0.6775	1.185	Cinders, large bits of charcoal, coal; little ash; very few spheres; animal hair; fibers and debris, bit of metal.	9
10	"	11:15	"	Grant Park; 100 ft. east of I.C.R.R.; opposite Jackson Blvd.	15x45	0.4356	1.370	Mostly cinders and ash; very little charcoal, wood or sand.	10
11	"	11:45	"	Michigan and Randolph; vacant lot east of Michigan	30x45	0.8710	1.275	Cinders; ash; charcoal; few ash spheres; few vegetable fibers; wood.	11
12	"	P.M. 12:30	"	Adams and Canal; roof of train shed of Union Depot.	15x60	0.5807	1.340	Cinders; ashes; numerous fused spheres of ash; mineral debris; fibers.	12
13	"	1:45	"	Halsted, south of Chicago, on curb space.	27x50	0.8710	1.340	Cinders; ashes; many fused spheres of ash; mineral debris; sand; bits of vegetable fiber, etc.	13
14	"	2:00	"	Vedder and Penn: Staton Playground.	30x56	1.0840	1.488	Cinders: ash; few spheres; sand; much fibrous material; mostly vegetable; wood, etc; much fine mineral and other matter, apparently few metallic particles.	14
15	"	2:30	"	Clybourn Place and Southport, vacant lot.	15x60	0.5807	1.555	Practically all cinders and ashes; some fibers.	15
16	"	3:00	"	Diversey and Paulina; vacant lot.	15x43	0.4162	1.630	Cinders; ash; many spherical fused ash particles; little sand; other mineral debris; little animal or vegetable matter; coal; charcoal or charred wood.	16
17	"	3:20	"	Logan Square	45x40	1.1610	1.633	Cinders; ash; numerous fibers; vegetable and animal: hair; much vegetable and mineral debris; few small spheres.	17
18	"	3:40	"	Humboldt Park; Music Court.	15x77	0.7451	1.435	Cinders; ashes; fibrous matter; vegetable and animal debris; shell of bug	18
19	"	4:00	"	Fulton and California; vacant lot	15x32	0.3096	1.664	Cinders; considerable sand; ash; spheres of ash; wood; animal hair; fibers; debris.	19
20	"	4:20	"	Carroll and Union Park Court; yard.	15x80	0.7742	1.408	Cinders; ash; some sand; mineral debris; woody fiber; some spheres of ash: vegetable fiber.	20
21	"	5:00	"	Washington and Canal; east of N. W. Station	15x84	0.8130	1.565	Cinders; ash; few spheres; sand; woody matter; few fibers; coal.	21
22	"	A.M. 9:45	"	Monroe, bet. Clark and La Salle; top of Harris Trust Building.	15x32	0.3096	1.786	Cinders; ash; few large ash spheres.	22

TABLE CXIV. ANALYSES OF SNOW SAMPLES COLLECTED WITHIN THE AREA OF INVESTIGATION

Test No	Weight in Milligrams															Composition of Solid Matter Per Cent							Test No
	Solid Matter			Ammonia			Nitrous Acid			Chlorin			Sulphuric Acid			Physical Classification			Chemical Classification				
	Total	Per Sq Meter	Per Liter	Total	Per Sq Meter	Per Liter	Total	Per Sq. Meter	Per Liter	Total	Per Sq Meter	Per Liter	Total	Per Sq Meter	Per Liter	Coarse Cinders	Fine Cinders	Dust	Ash	Tar	Sulphur	Carbon	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	116	240.0	93.48	0.170	0.351	0.1400	0.0305	0.0631	0.0251	4.32	8.93	3.56	11.78	21.34	9.605	0.00	33.44	66.56	82.50	N.D.*	N.D.	17.50	1
2	123	282.0	92.80	0.282	0.647	0.2130	0.0335	0.0765	0.0251	5.30	12.17	4.00	15.60	35.80	11.800	0.00	8.46	91.54	59.16	"	"	40.84	2
3	162	372.0	133.00	0.267	0.613	0.2190	0.0305	0.0701	0.0251	4.34	9.96	3.56	15.00	34.30	12.300	0.00	7.77	92.23	62.50	"	"	37.50	3
4	448	873.0	327.00	0.416	0.811	0.3040	0.0344	0.0671	0.0251	6.09	11.87	4.44	15.90	31.00	11.600	0.00	26.80	73.20	58.00	"	2.05	39.97	4
5-6	5032	7764.0	3690.00	1.830	2.810	1.3400	0.0386	0.1050	0.0505	11.52	17.77	8.44	74.90	115.50	54.900	33.61	40.13	20.26	51.05	1.15	0.95	46.85	5-6
7	301	518.0	223.00	0.410	0.706	0.3040	0.0339	0.0584	0.0251	7.20	12.40	5.33	13.90	23.90	10.300	0.00	26.08	73.92	62.00	N.D.	0.27	37.73	7
8	474	816.0	351.00	0.492	0.848	0.3650	0.0339	0.0584	0.0251	7.80	13.43	5.78	30.80	53.00	22.800	0.00	38.71	31.29	61.00	"	0.14	38.86	8
9	334	493.0	282.00	0.324	0.478	0.2740	0.0655	0.0967	0.0553	6.32	9.33	5.33	15.90	23.50	13.500	6.68	25.62	67.70	47.00	"	0.99	52.01	9
10	634	1456.0	463.00	0.291	0.669	0.2130	0.0367	0.0843	0.0268	10.96	25.16	8.00	23.20	53.20	16.900	0.00	52.84	47.16	39.50	"	1.20	59.30	10
11	1153	1324.0	904.00	0.736	0.845	0.5780	0.0470	0.0540	0.0369	9.63	11.06	7.56	41.80	47.90	32.700	0.00	45.97	53.34	62.50	3.25	0.82	33.43	11
12	624	1075.0	466.00	1.140	1.960	0.8510	0.0449	0.0773	0.0335	8.33	14.36	6.22	25.60	44.10	19.100	3.13	30.37	66.50	58.50	N.D.	1.31	40.19	12
13	1148	1318.0	857.00	0.855	0.982	0.6380	0.0404	0.0464	0.0302	8.33	9.57	6.22	42.00	48.20	31.300	4.31	44.16	51.53	51.75	4.25	0.20	43.80	13
14	421	388.0	282.00	0.452	0.417	0.3040	0.0524	0.0483	0.0352	7.28	6.71	4.89	35.10	32.40	23.600	0.00	18.91	81.07	57.15	N.D.	0.49	42.36	14
15	932	1610.0	601.00	1.130	1.950	0.7290	0.0573	0.0967	0.0367	13.13	22.61	8.45	43.00	74.00	27.600	0.00	36.23	63.77	69.25	3.00	0.77	26.98	15
16	671	1612.0	412.00	0.743	1.790	0.4560	0.0546	0.1312	0.0335	7.25	17.41	4.44	23.60	56.60	14.500	0.00	21.46	78.54	68.50	N.D.	0.80	30.70	16
17	41	35.3	25.10	0.149	0.128	0.0312	0.0301	0.0259	0.0184	4.35	3.75	2.67	2.67	2.30	1.640	Sample obtained insufficient for analysis.							17
18	54	72.5	37.60	0.139	0.187	0.0973	0.0240	0.0323	0.0168	2.55	3.42	1.78	2.32	3.11	1.620	"	"		"	"	"		18
19	454	1466.0	273.00	0.222	0.718	0.1340	0.0362	0.1170	0.0218	6.66	21.49	4.00	10.13	32.70	6.090	0.00	48.02	51.98	55.00	N.D.	1.68	43.32	19
20	386	499.0	274.00	0.770	0.995	0.5470	0.0401	0.0518	0.0285	4.38	5.66	3.11	14.90	19.20	10.600	6.48	37.31	56.21	58.50	"	0.55	40.95	20
21	2994	3684.0	1913.00	0.951	1.170	0.6080	0.0603	0.0742	0.0385	16.00	19.67	10.22	210.00	258.30	134.200	0.00	41.82	58.18	61.40	1.10	0.96	36.54	21
22	3757	12120.0	2104.00	1.740	0.561	0.9730	0.0479	0.1546	0.0268	50.00	161.50	28.00	195.10	630.00	109.200	0.81	57.23	11.96	67.10	1.55	0.55	30.80	22

* "N. D." indicates a sample insufficient to warrant the determination.

In order to present an idea of the character and relative amounts of the solid materials collected from each sample of snow, photographs were made of the filters and their contents. These are presented as figs. 70 and 71. The halftones are four centimeters in diameter, or four-ninths of the actual size of the filters.

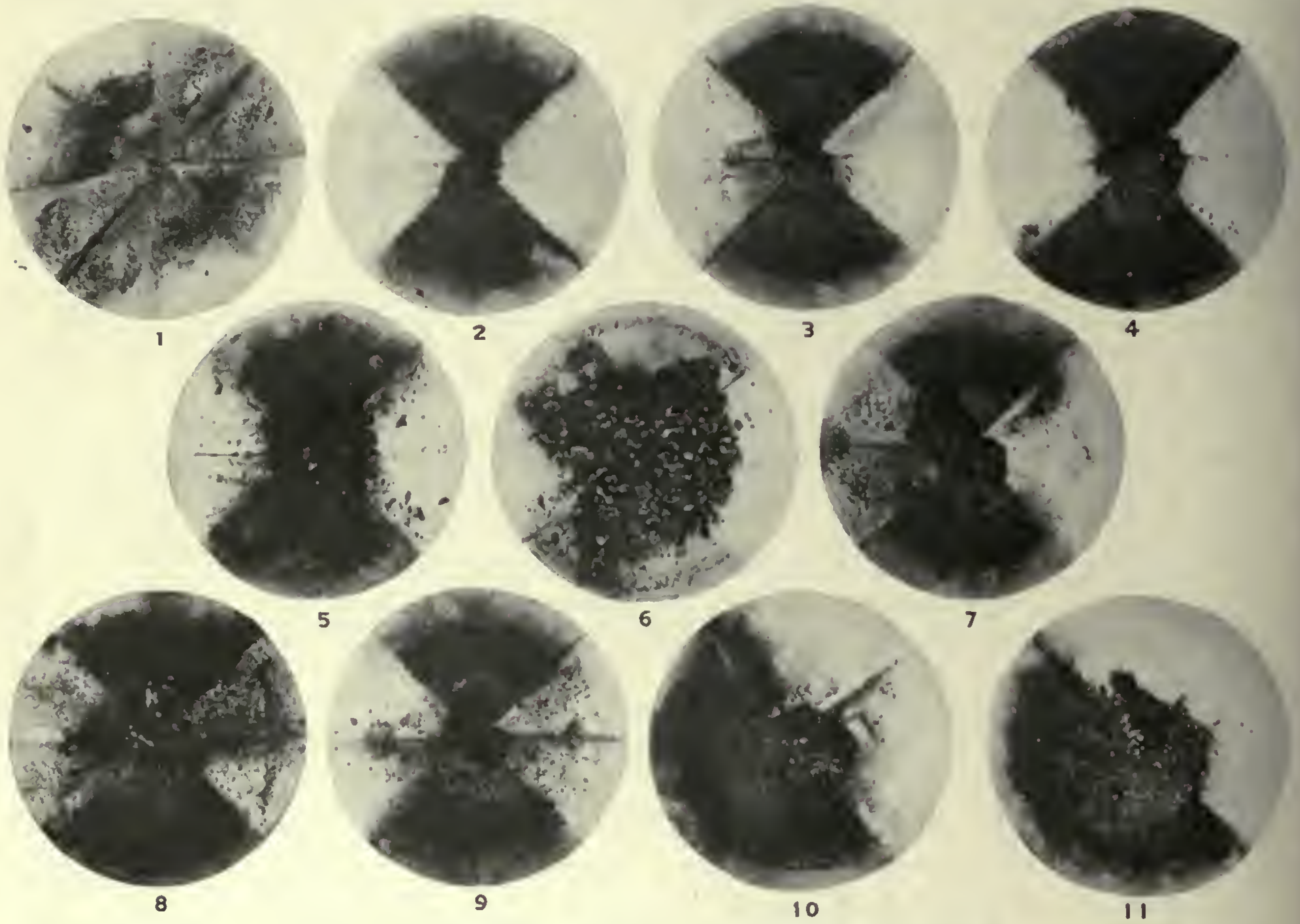


FIG. 70. RESIDUE FROM FILTRATION OF SNOW SAMPLES
Filters Nos. 1 to 11

Solid materials which remained upon the filter paper were divided into two classes, heavy material which did not float on water and light material which formed a film on the surface of the water. It was noted that, upon drying, this light material tended to stick together or to cake. Examples of the light materials are shown by the illustrations of filters Nos. 2, 5, 7, 9, 13 and 16. The difference between the amount of solid materials found in the samples collected in parks and that obtained from samples collected in populous districts becomes apparent when the illustrations of filters Nos. 1, 17 and 18 are compared with the others of the series. The illustration of filter No. 2 shows the residue from a sample collected in a residential district, at a point about one mile distant from the location at which "Park" sample No. 1 was collected. The samples of snow collected from the parks of the city show only slight evidence of the presence of soot, while those collected in residential, business and industrial districts indicate the presence of considerable quantities of the products of combustion.

As has been previously stated, the surface of the ground was entirely covered with snow at the time these samples were collected, and only a few hours had elapsed between the time of the snowfall and the collection of the samples. For this reason it seems evident that solid materials and other polluting substances detected in the snow samples must have been suspended in the atmosphere at time of precipitation, the snow acting as a purifier of the atmosphere. The only other apparent explanation of the presence of these substances is that they had been deposited upon the surface of the snow during the period between the snowfall and the time of collection. In either case, comparisons of the samples yield excellent data regarding the relative degrees of pollution of the atmosphere at the various points of collection. The facts disclosed by such comparisons will be discussed later in connection with the various substances.

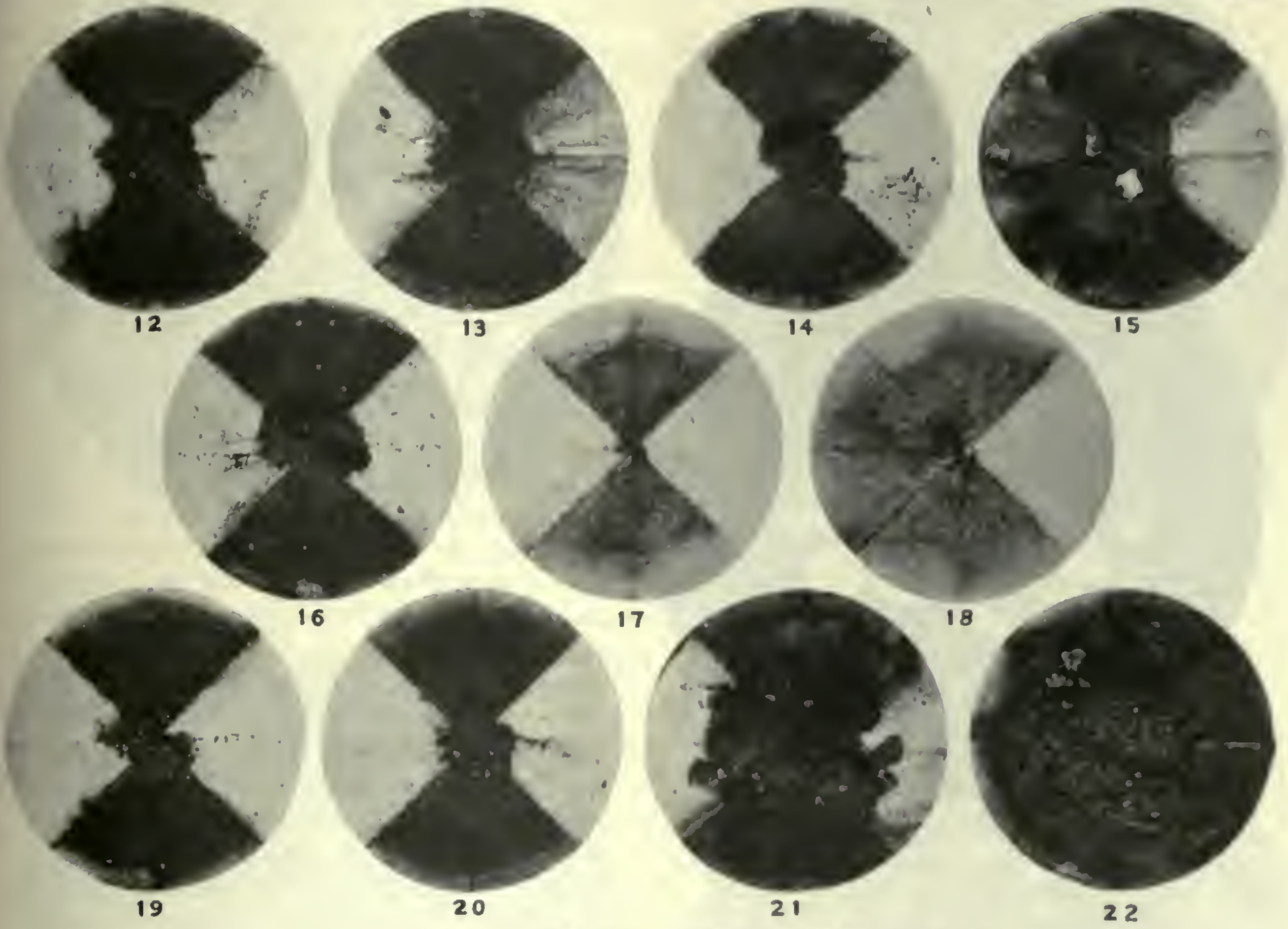


FIG. 71. RESIDUE FROM FILTRATION OF SNOW SAMPLES
Filters Nos. 12 to 22

A microscopical examination of the solid materials collected revealed the fact that practically all of the samples of snow contained soot, ash, cinders and mineral debris, in addition to a variety of other substances. In some of the samples were found fused particles of ash, which probably had passed from the stack and had fallen to the ground without coming in contact with other bodies until cold. The great variety of solid substances identified in the samples indicated a wide range and an extensive distribution of the sources of pollution.

Reproductions of photomicrographs of the solid particles found in the snow samples are presented as figs. 72 and 73. Fig. 72 shows a collection of spheres of fused ash. Fig. 73 shows various solid substances as found on the filters.

The values obtained from the analyses of snow samples were based upon the unit of one liter of melted snow. An attempt was made to obtain values upon the basis of the surface area removed in obtaining the sample, but these results presented such wide variation that they were discarded. The values per liter of melted snow present greater uniformity than the similar values obtained from the analyses of rain water samples.

A study of the numerical results obtained from the analyses of snow samples indicates that the greatest amounts of solid polluting substances detected occurred in the case of those samples collected in or near the centers of greatest commercial or industrial activity. The values, in practically all cases, diminished directly as the distance of the point of collection from the loop district increased. Exceptions to this rule occurred in the case of sample No. 5-6, which was collected in the neighborhood of packing plants, and in the case of sample No. 15, which was collected at a point in the neighborhood of factories. The quantity of impurities found in snow sample No. 12, which was collected from the roof of a train shed, was not so great as the amount found in samples taken from the ground at a short distance from railroad terminals. It was difficult to determine, however, whether the factor of distance from the loop district, or that of local conditions, was most effective in influencing the amount of pollution found in the sample, nor is it possible to state whether the relatively large amounts of polluting substances found in the samples collected in or near the loop district were due to the presence of railroad terminals or to other activities.

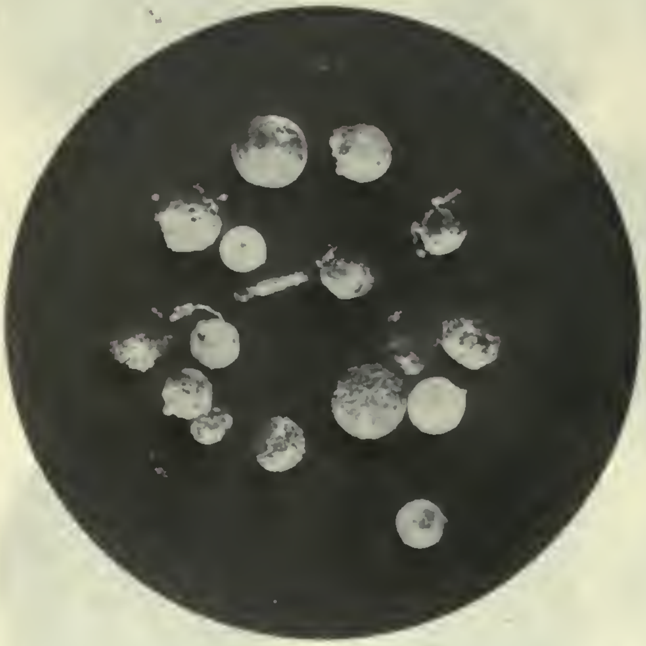


FIG. 72. PHOTOMICROGRAPH. Fused Particles of Ash Found in Snow Samples. Magnification, 30 Diameters.

The results of the analyses arranged in relation to the distance of point of collection from the loop district are presented diagrammatically as fig. 74.

The study of the numerical results of the examinations of the snow samples also revealed an apparent relationship between the various constituents. All substances, for instance, seemed to increase in direct ratio with the increase of the ammonia content. A rearrangement of the results according to the ascending values for ammonia is presented as fig. 75.

The higher values for sulphuric acid appeared, as a rule, in the analyses of samples collected near railroad yards or terminals. The only exceptions to this occurred in the case of two samples collected near playgrounds located in thickly settled communities.

The results obtained from the physical classification of the solid materials indicated that the larger amounts of coarse cinders occurred in the case of samples collected near the railroads. Only one exception to this rule was noted.

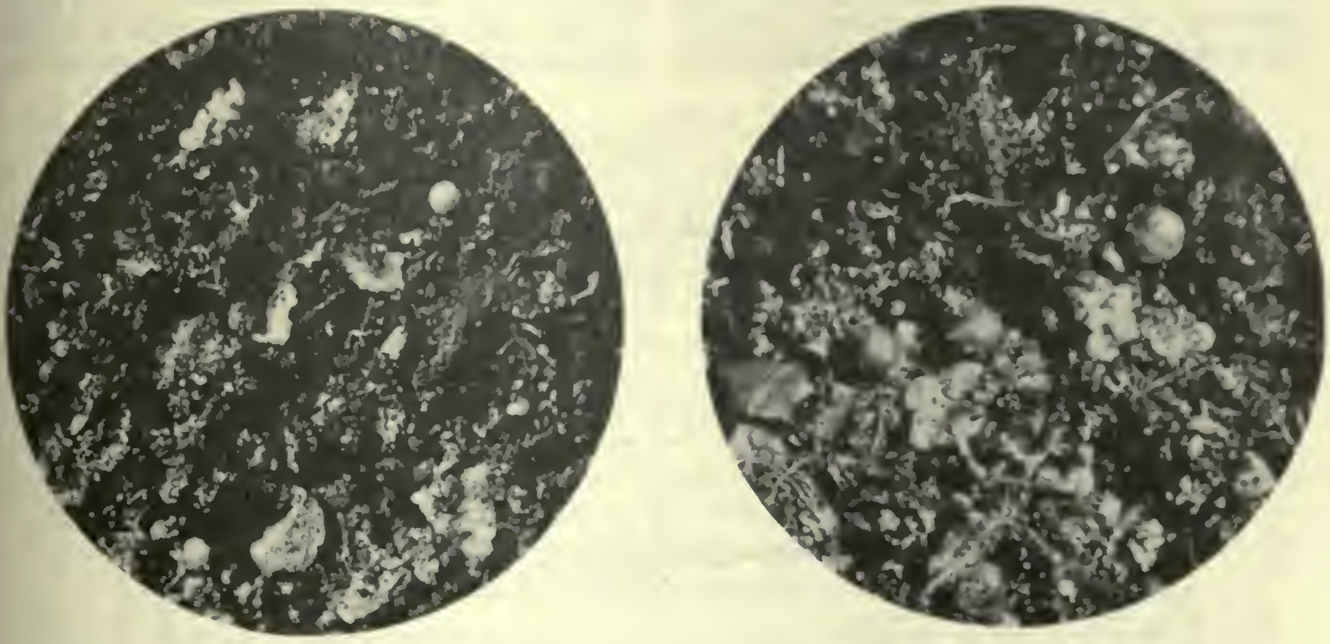
Determinations for tar in the solid materials collected were made only in the case of samples which were of sufficient magnitude to exceed one gram in weight. Samples of such size were obtained only in instances where the point of collection was located near a railroad line or terminal. The fact that no tar determinations were made in samples from residential, park or other districts does not indicate that the deposits in such districts were free from tar. In reality, the determinations emphasize the fact that solid materials containing soot and cinders contain also, in practically all cases, a considerable percentage of tarry matter. When mixed with water, these tarry samples possess a tendency to "crawl" or to spread readily over a smooth surface. The resulting stains are not easy to remove.

The percentages of sulphur found in the solid materials taken from the samples of snow were generally lower than those found in samples of coal. The presence of sulphur in these solid materials, however, emphasizes the fact that the deposits from the atmosphere may exert a corrosive influence upon materials with which they come in contact, since the sulphur may be present as sulphuric acid, or in some form readily convertible to sulphuric acid under normal atmospheric conditions. A change from sulphur to sulphuric acid effects an increase in the weight of the constituent in the proportion of 32 to 98.

A comparison of the results of the analyses of snow with those of rain water yields some facts of interest. Conversion of the averages in both cases to the basis of the number of milligrams per liter, shows that values obtained from the rain water analyses were higher than those from the snow analyses. This comparison is as follows:

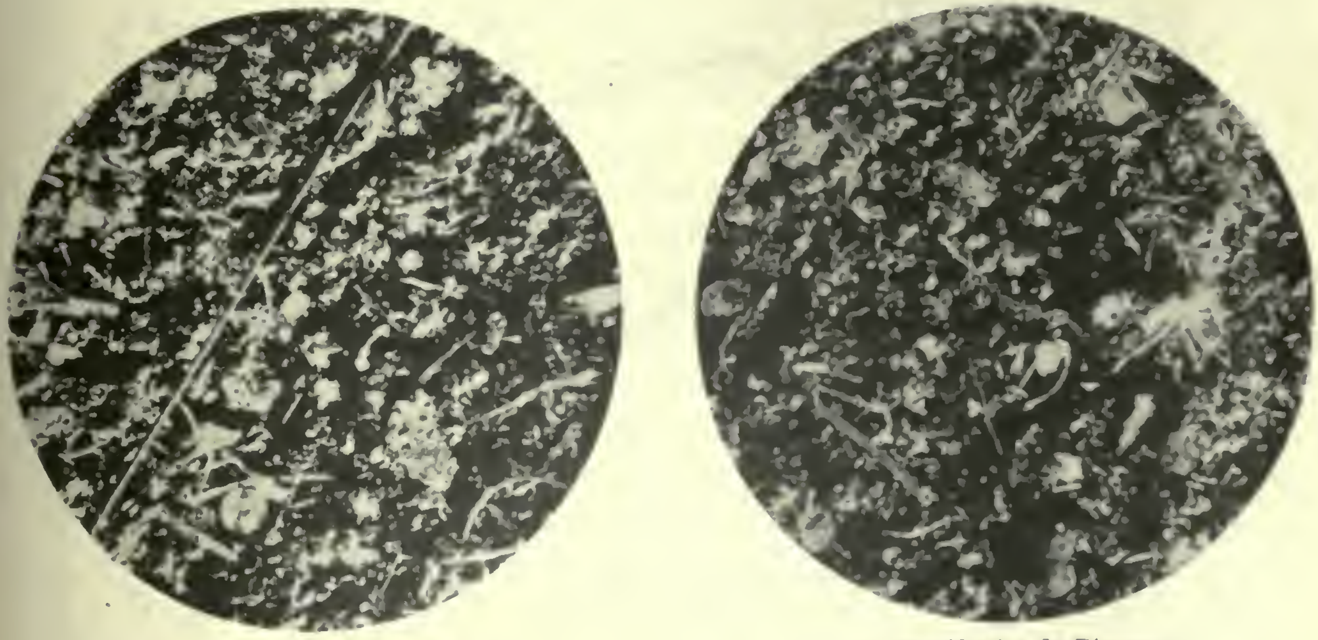
	NH_3	Cl	HNO_2	H_2SO_4
Average for 18 rain analyses	0.905	8.15	0.1865	144.2
Average for 21 snow analyses	0.447	6.48	0.0305	27.4

A comparison of the results of snow and rain analyses, in cases where samples were collected near the same points, also indicates that in a majority of cases the rain values were higher than the snow values. Such a comparison is presented in the following tabulation:



1. Magnification, 34 Diameters (Sample No. 4)

2. Magnification, 34 Diameters (Sample No. 8)



3 Magnification, 34 Diameters (Sample No. 14)

4. Magnification, 34 Diameters (Sample No. 17)

FIG. 73. PHOTOMICROGRAPHS OF SOLID MATERIALS FOUND IN SNOW SAMPLES

MILLIGRAMS PER LITER OR PARTS PER MILLION

	Sample No.	HNO2	NH3	Cl	H2SO4
Rain	27	0.118	0.912	18.0	67.3
Snow	14	0.035	0.304	4.9	23.6
Rain	42B	0.208	0.730	0.0	——
Snow	8	0.025	0.365	5.8	22.8
Rain	116	0.040	2.056	7.8	108.2
Snow	11	0.037	0.578	7.6	32.7
Rain	64	0.322	0.532	18.2	845.0
Snow	13	0.030	0.638	6.2	31.3

It will be noted that in only three instances did the individual results deviate from the general rule established by the averages. In one instance sulphur in rain water was not determined and in the other two instances the results were almost identical.

Thus it would appear that rain is a more effective purifier of the atmosphere than snow, or that the amount of impurities present in the atmosphere in summer is greater than in winter.

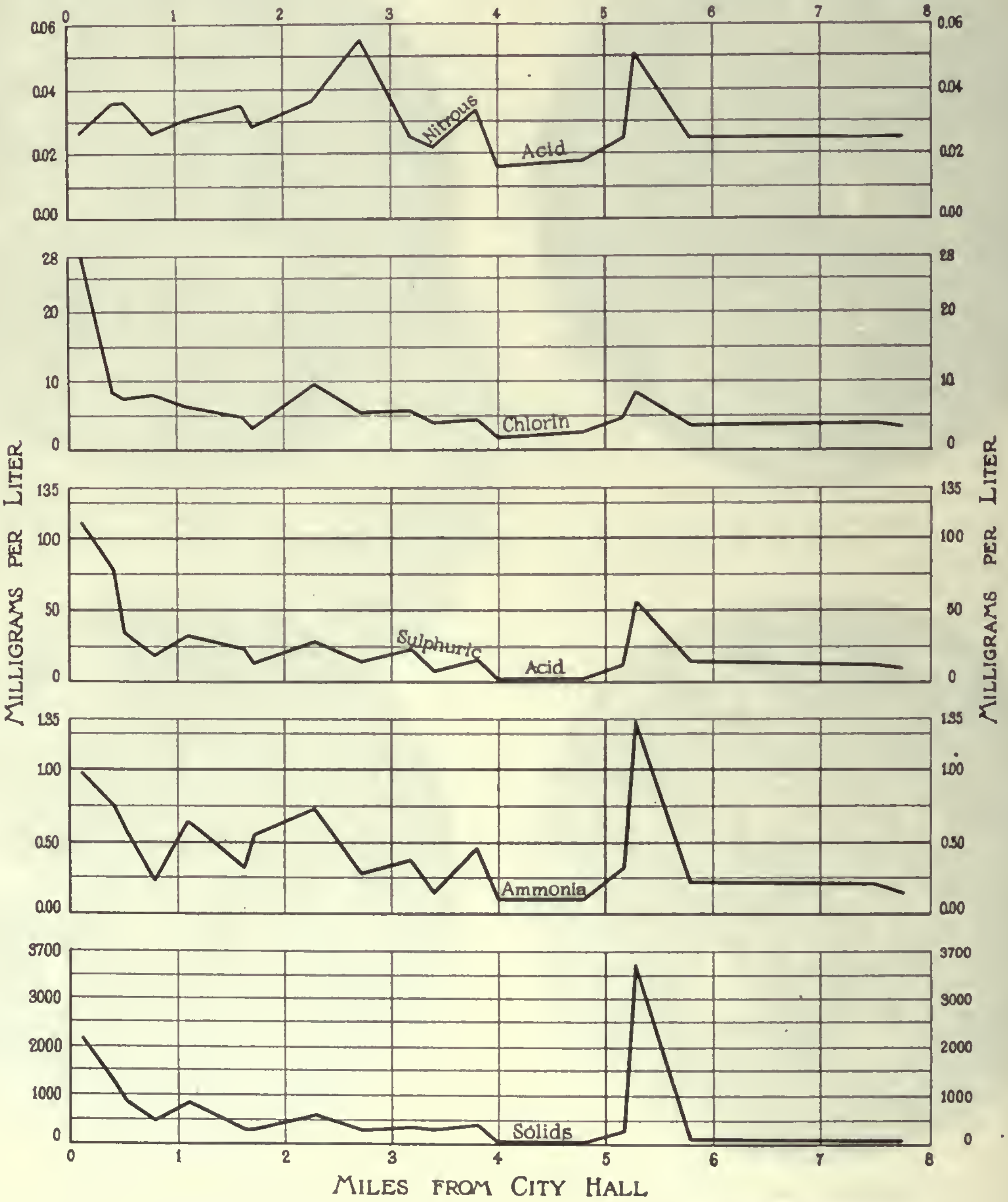


FIG. 74. RESULTS OF SNOW ANALYSES ARRANGED ACCORDING TO DISTANCE OF POINT OF COLLECTION FROM THE LOOP DISTRICT

113.14 Composition of the Atmosphere, as Disclosed by Analyses of Air Samples: In order to provide a portable laboratory suited to the requirements of this investigation, a simple but spacious automobile of the delivery type was equipped with the various apparatus and materials needed. The machine was driven by a gasoline motor, and was equipped with a storage battery for supplying power for electric lights and for the operation of the electric motor used for driving the air pump. The body of the automobile was designed to be closed and locked when desired. Adequate protection was provided against cold in winter. Views of the automobile laboratory are presented as figs. 76 and 77.

The absorption apparatus used in analyses of air samples consisted of a series of flasks containing proper solutions and arranged as shown by fig. 78.

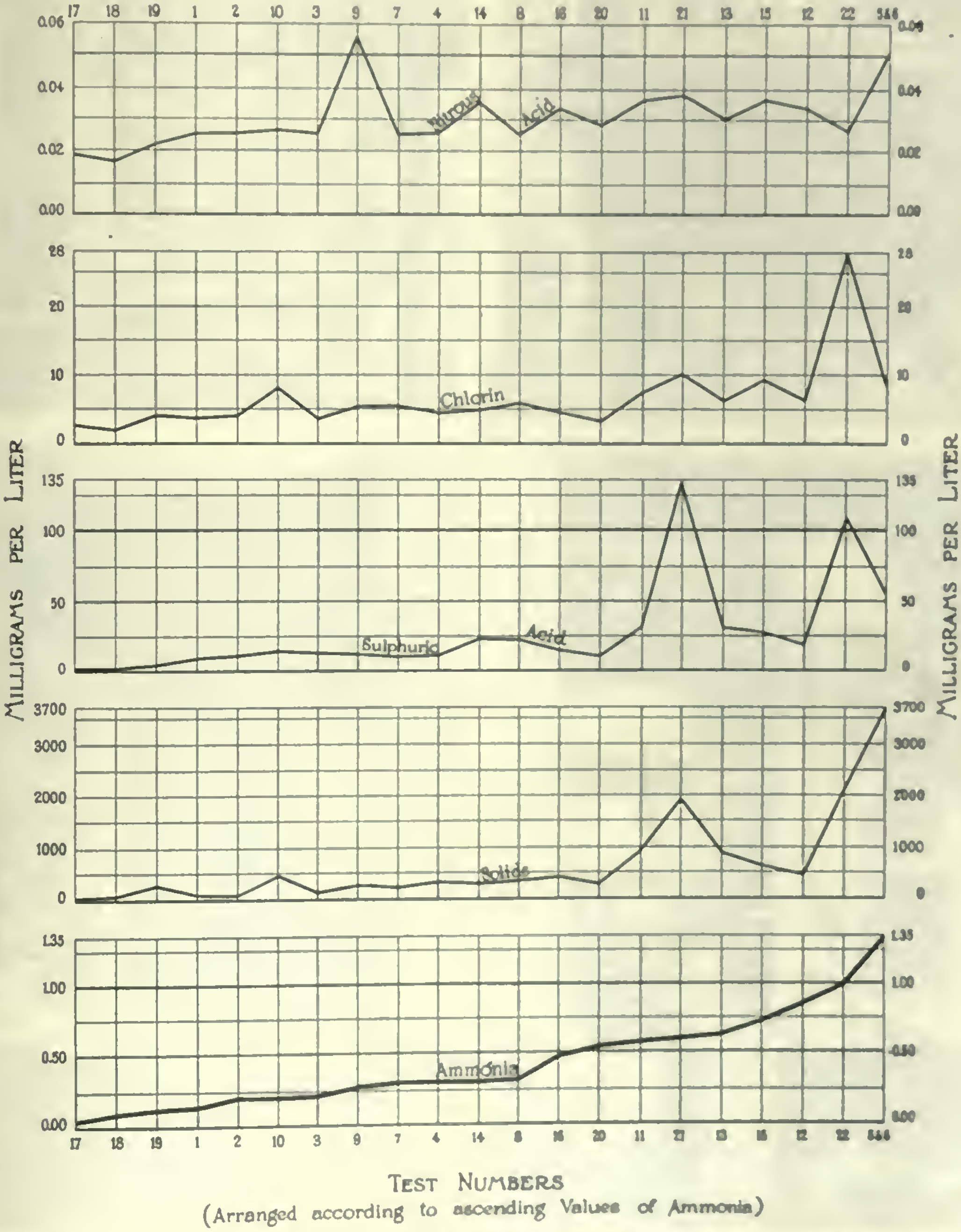


FIG. 75. RESULTS OF SNOW ANALYSES ARRANGED ACCORDING TO THE ASCENDING VALUES FOR THE AMMONIA CONTENT

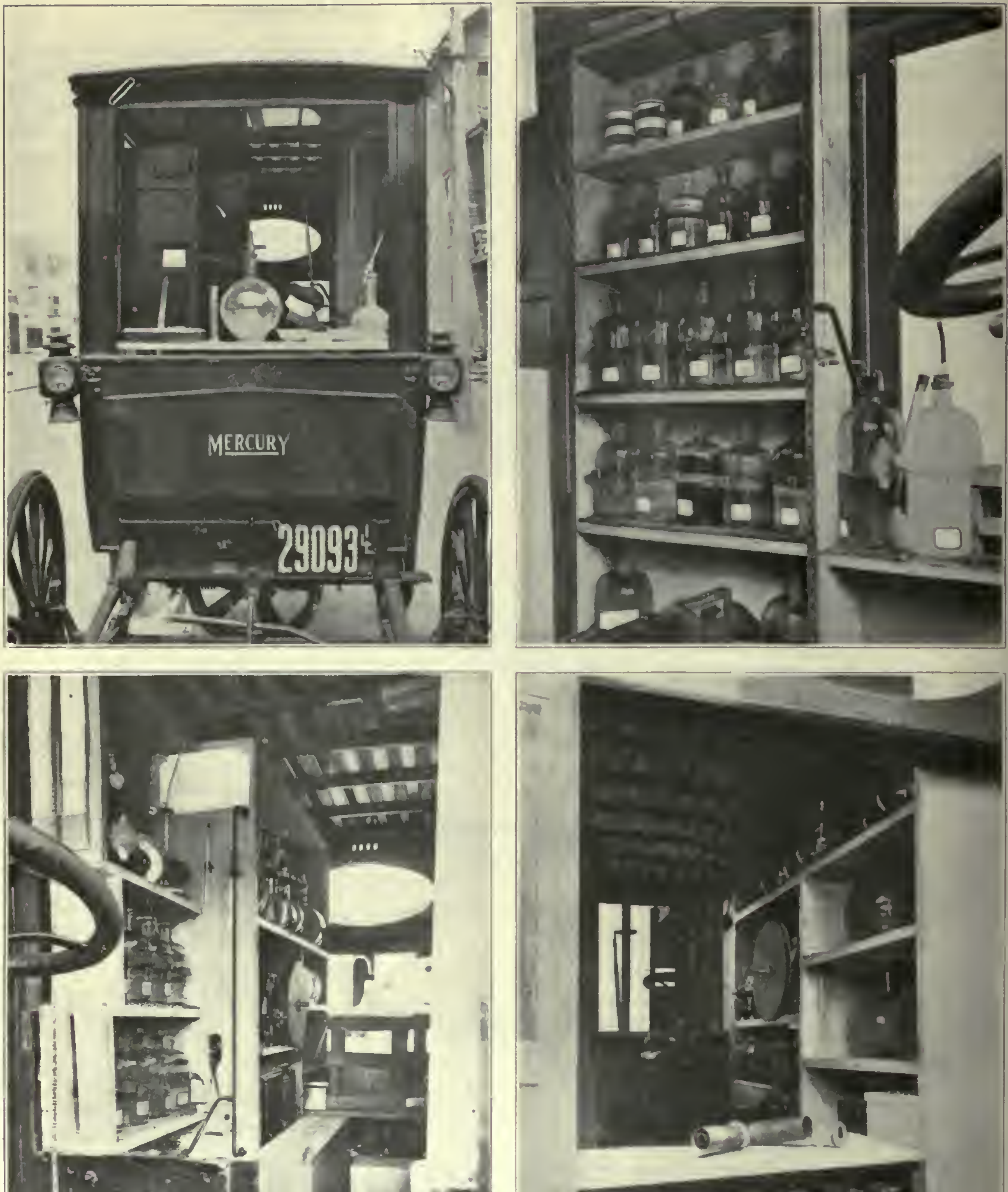
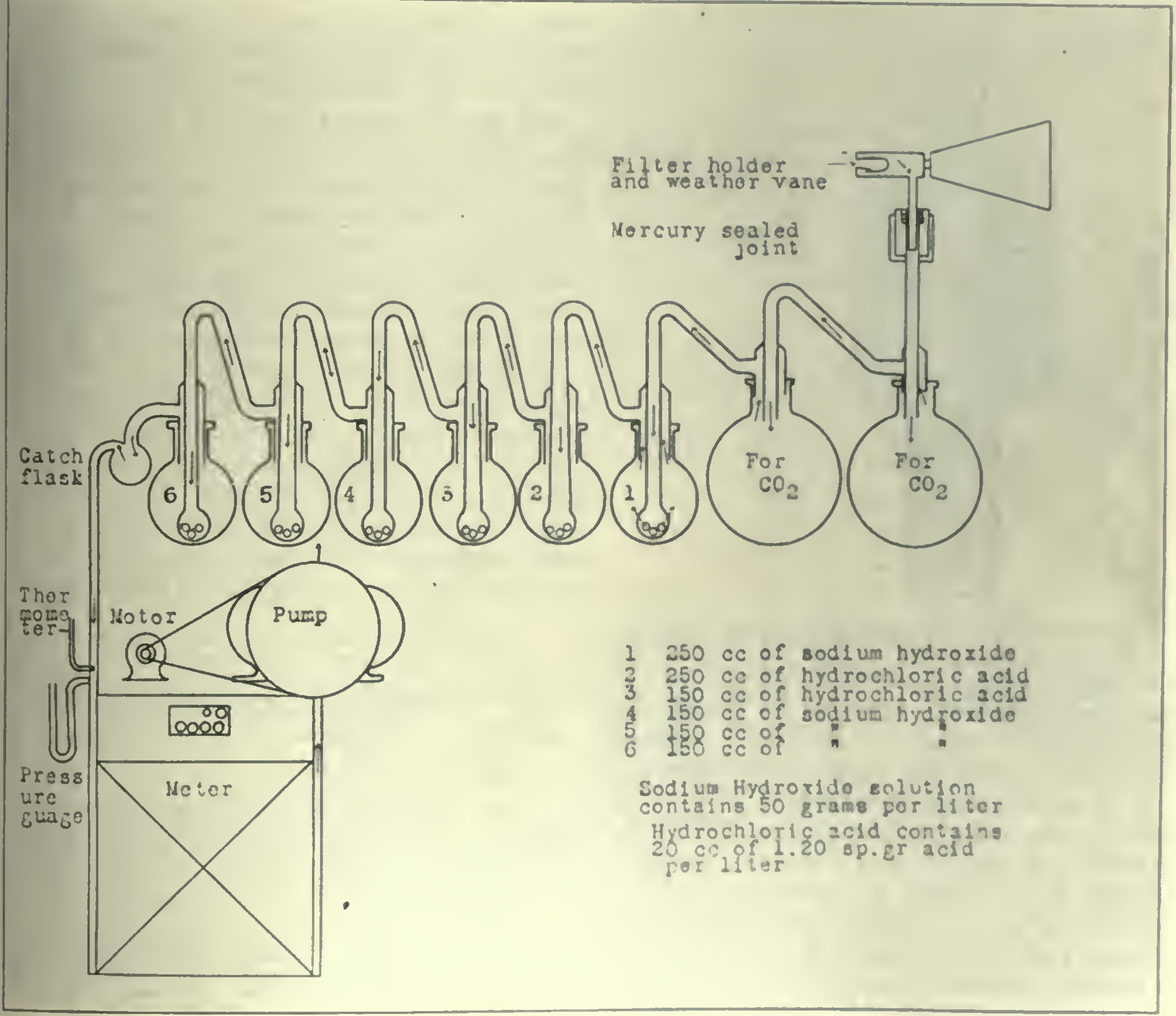


FIG. 76. VIEWS OF PORTABLE LABORATORY

FIG. 77. PORTABLE LABORATORY

The holes in the bottom of the bulbous tube, through which the air passed into the solution, were approximately two millimeters in diameter and of sufficient number to prevent appreciable resistance to the flow of air through the apparatus. The separation may not have been exact between all of the flasks, but the method proved reliable for work of this character in which an accurate comparison only was desired. Very little material was carried over from one flask to another, and the last flask, which was used merely as a trap, was moistened only during a test. There was a concentration of the solution in the first flask (No. 1) due to lack of moisture in the air. During the daytime the evaporation from this flask,



1 250 cc of sodium hydroxide
2 250 cc of hydrochloric acid
3 150 cc of hydrochloric acid
4 150 cc of sodium hydroxide
5 150 cc of " "
6 150 cc of " "

Sodium Hydroxide solution contains 50 grams per liter

Hydrochloric acid contains 20 cc of 1.20 sp.gr acid per liter

FIG. 78. ABSORPTION APPARATUS USED IN ANALYSES OF AIR SAMPLES

which in some cases amounted to 100 cubic centimeters, was compensated by the addition of water or alkaline solution.

The filter holder was designed to face the wind at all times, its position being controlled by a vane. To prevent air leakage it was set in a mercury-sealed ball-bearing swivel joint. All parts which came in contact with the mercury were of iron; the remaining parts were of brass. While the automobile was in transit, all apparatus above the mercury seal was removed. When not in use, the filter proper was protected by means of a cork inserted in the end of the holder. The filter holder and mercury seal are illustrated by fig. 79.

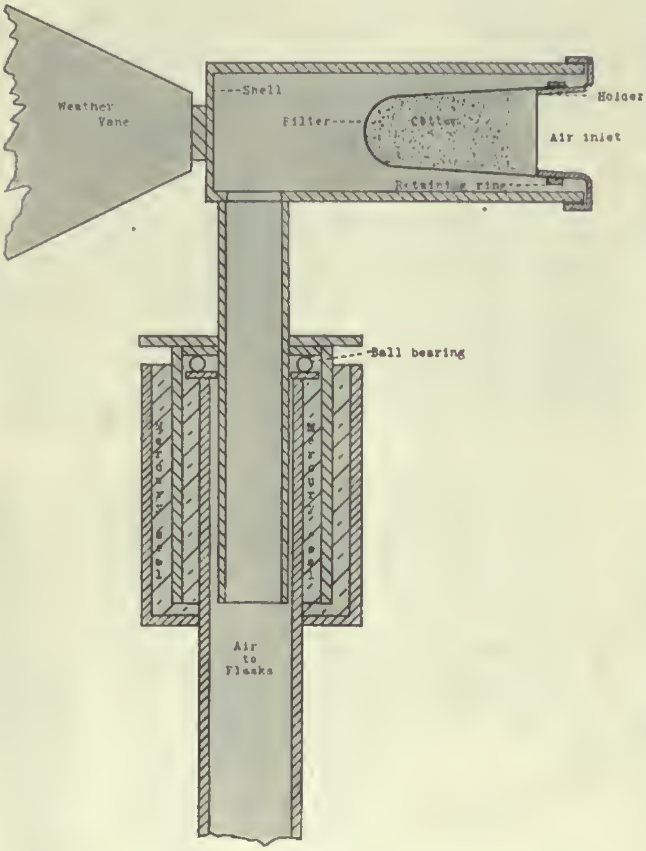


FIG. 79. FILTER HOLDER AND SEALED JOINT

The procedure of conducting a test was as follows: The automobile was driven to the point of collection selected, and placed as nearly as possible in a position in which it would not interfere with street traffic. For night tests a position was selected near an electric street lamp, if possible, so that readings could be easily taken from instruments which were used outside of the automobile. When the automobile was properly located, the air filter was set in place and all necessary apparatus was assembled. After the apparatus was arranged for the test, the meter reading was recorded and the flow of air through the apparatus was started. Other reference data, such as humidity, temperature and barometric pressure, were recorded as required in each test.

After a volume of about 90 cubic feet of air had passed through the apparatus, a process which usually required about 30 minutes, the first two flasks of the series were removed and new flasks were substituted. The samples of air contained in these first flasks were tested for carbon dioxid according to the method hereinbefore described (section 105.37). The other constituents of the atmosphere for which values were desired, were determined from analyses of the solutions contained in the remaining flasks of the series upon the completion of the tests.

113.15 Records and Results of Air Analyses: The records of any research are almost as important as the final results. In this investigation, a complete record was kept of all conditions affecting each test, and from this was prepared a condensed record of conditions and results. Typical records for a test, and the condensed record of results made therefrom, are illustrated by fig. 80.

While the results are given to four or five decimal places, in many cases, the accuracy of the fourth significant figure is sometimes questionable. A summary of results is presented as tables CXV to CXXIV inclusive.

A brief description of the contents of the filters, and of conditions which might affect the results of the different tests, is presented in the following:

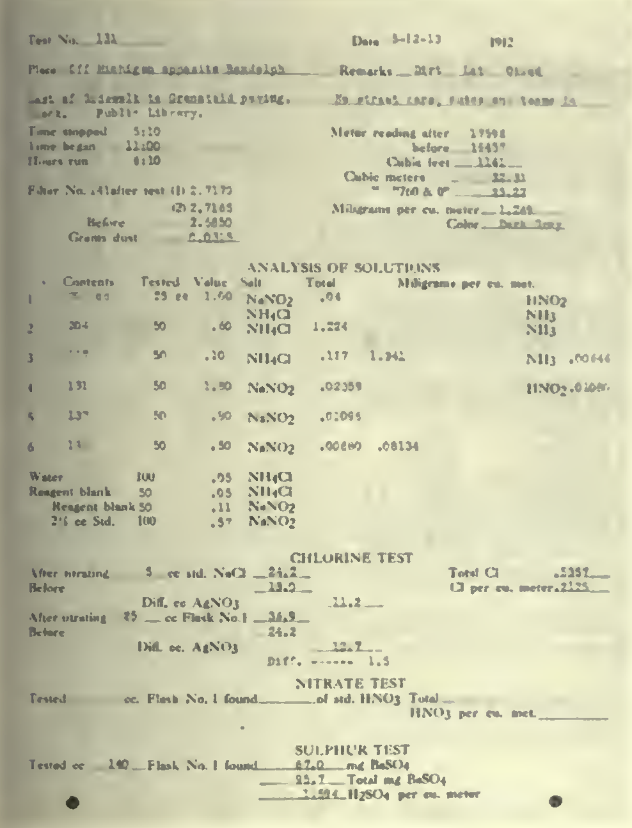
SUMMARY OF THE CONTENTS OF FILTERS AND OF CONDITIONS AFFECTING TESTS

TEST NUMBER AND LOCATION	FILTER NUMBER, COLOR AND MATERIAL IDENTIFIED	CONDITIONS UNDER WHICH TESTS WERE MADE
	COUNTRY	
125 La Grange, Kensington and Oak, May 2, 1913.	139. Light gray. Fairly coarse mineral debris, ash, few pieces of cinder, no soot, insect parts, vegetable fibrous matter, sphere or two.	Houses quite numerous, nearest 100 feet N., ½ block S., vacant grass lots S., gravel pike not oiled, wind blowing through town.
135 La Grange, 5th Ave. and Oak, May 19, 1913.	145. Very light gray. Few cinders, mineral debris, ash, organic debris, numerous plant hairs, few small ash spheres.	Open meadow E., R.R. ½ mile E., houses two blocks N. and S. and ½ block W., gravel road. N. E. wind.

136 La Grange, 5th Ave. south of 47th, May 21 and 22, 1913.	147. Slightly gray. Vegetable hair, number of pollen, few ash pieces, a sphere or two and a little mineral debris.	Golf links E., meadow W., gravel road, rain day before, houses ¼ mile N. One block W. quarries and Argo S. E.
137 La Grange, Kensington and North, May 23, 1913.	148. Very light gray. Very little animal debris, few cinders, organic debris.	Meadow N., woods beyond; greenhouse N. E. one mile. Houses N. W. ¼ mile and S. 100 feet, mud road with no traffic.

PARKS

110 Logan Square, March 31, 1913.	116. Light. Probably some road dirt, much coarse mineral debris, ash, few cinders and coal, organic debris and fiber.	Rain during night, asphalt street and macadam road.
111 Humboldt Park, Music Court, April 1, 1913.	117. Almost white. Mineral debris, ash, few cinders and soot, coal, fibers, organic debris, vegetable matter, wood, few ash spheres.	Gravel, open space between boathouse and pavilion, meadow across boulevard W.



Test No. 131 Date 5-12-13 1912

Place Off Michigan opposite Randolph Remarks Dirt Lot Oiled

[illegible] Public Library. No street cars, [illegible]

Time stopped 5:10
Time began 11:00
Hours run 6:10

Meter reading after 17598
before 16437
Cubic feet 1161
Cubic meters 32.88
" "760 & 0" 25.22

Filter No. 141 after test (1) 2.7173
(2) 2.7165
Before 2.6850
Grams dust 0.0315

Milligrams per cu. meter 1.249
Color Dark Grey

ANALYSIS OF SOLUTIONS

	Contents	Tested	Value	Salt	Total		Milligrams per cu. met.
1	[illegible]	25 cc	1.60	$NaNO_2$	.04		HNO_2
				NH_4Cl			NH_3
2	304	50	.60	NH_4Cl	1.224		NH_3
3	[illegible]	50	.10	NH_4Cl	.117	1.342	NH_3 .00646
4	131	50	1.50	$NaNO_2$	.02359		HNO_2 .0108
5	137	50	.90	$NaNO_2$	.02095		
6	[illegible]	50	.50	$NaNO_2$	.00680	.08134	
Water		100	.05	NH_4Cl			
Reagent blank		50	.05	NH_4Cl			
Reagent blank		50	.11	$NaNO_2$			
2½ cc Std.		100	.57	$NaNO_2$			

CHLORINE TEST

After titrating 5 cc std. NaCl 24.2 Total Cl .5357
Before 13.0 Cl per cu. meter .2125
Diff. cc $AgNO_3$ 11.2
After titrating 25 cc Flask No. 1 36.9
Before 24.2
Diff. cc. $AgNO_3$ 12.7
Diff. ------ 1.5

NITRATE TEST

Tested ____ cc. Flask No. 1 found ____ of std. HNO_3 Total ____
HNO_3 per cu. met. ____

SULPHUR TEST

Tested cc 140 Flask No. 1 found 67.0 mg $BaSO_4$
93.7 Total mg $BaSO_4$
1.594 H_2SO_4 per cu. meter

Typical Record for a Test

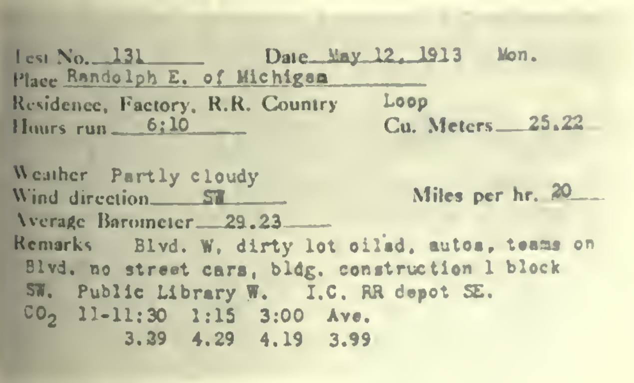
WEATHER CONDITIONS

CARBON DIOXIDE

Average 3.99

Over titrated

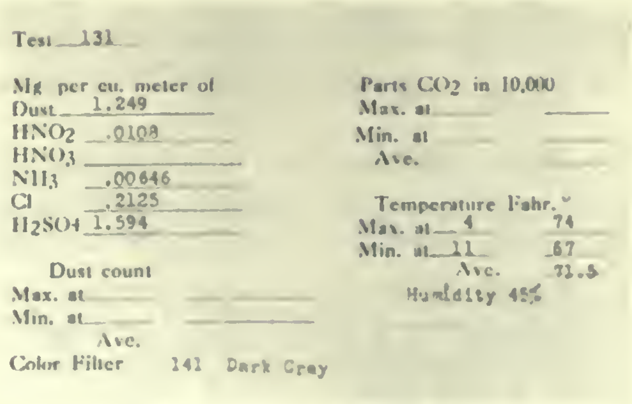
Typical Record for a Test



Test No. 131 Date May 12, 1913 Mon.
Place Randolph E. of Michigan
Residence, Factory, R.R. Country Loop
Hours run 6;10 Cu. Meters 25.22

Weather Partly cloudy
Wind direction SW Miles per hr. 20
Average Barometer 29.23
Remarks Blvd. W. dirty lot oiled, autos, teams on Blvd. no street cars, bldg. construction 1 block SW. Public Library W. I.C. RR depot SE.
CO_2 11-11:30 1:15 3:00 Ave.
3.39 4.29 4.19 3.99

Condensed Record of Results of a Test



Test 131

Mg per cu. meter of
Dust 1.249
HNO_2 .0108
HNO_3 ____
NH_3 .00646
Cl .2125
H_2SO_4 1.594

Dust count
Max. at ____
Min. at ____
Ave.
Color Filter 141 Dark Grey

Parts CO_2 in 10,000
Max. at ____
Min. at ____
Ave.

Temperature Fahr.°
Max. at 4 74
Min. at 11 67
Ave. 71.5
Humidity 45%

Condensed Record of Results of a Test

FIG. 80. TYPICAL RECORD FOR A TEST AND CONDENSED PERMANENT RECORDS OF RESULTS

TABLE CXV. OBSERVED DATA AND RESULTS OF AIR ANALYSES
COUNTRY DISTRICT

Test No.	Date	Duration of Test Hr. Min.	Volume Cubic Meters	Wind Dir. and Velocity Mi. per Hr.	Temperature Deg. F.	Relative Humidity Per Cent	Barometric Pressure Inches	Carbon Dioxid Parts in 10,000	Filter		Milligrams per Cubic Meter					Test No.	Test Location	Remarks
									No.	Color	Solids	Nitrous Acid	Ammonia	Chlorin	Sulphuric Acid			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
123	4-30-13	6 00	24.83	SW 11	74.0	44	29.19	3.36	136	Filter injured	....	.00150	.00716	.1030	.0343	123	7th Ave. south of 47th	LaGrange
124	5- 1-13	5 45	21.31	SW 18	82.0	36	29.06	3.42	138	" "	....	.00206	.00591	.0000	.1142	124	Goodman and Park Road	"
125	5- 2-13	5 55	21.50	SW 20	82.0	32	29.00	3.29	139	Slightly gray	.023	.00160	.00537	.0490	.2625	125	Kensington and Oak	"
135	5-19-13	5 40	23.81	NE 14	57.7	55	29.43	2.90	145	Very light gray	.168	.00190	.00329	.0000	.0000	135	Fifth Avenue and Oak	"
136	5-21-13	10 55	38.52	W-SW 17	62.2	79	29.16	3.06	147	" " "	.003	.00085	.00613	.0000	.0000	136	Fifth Ave. south of 47th	"
137	5-23-13	6 00	25.10	N 11	54.0	85	29.35	2.98	148	" " "	.000	.00130	.00536	.0000	.0000	137	Kensington and North	"

TABLE CXVI. OBSERVED DATA AND RESULTS OF AIR ANALYSES
PARK DISTRICTS

Test No.	Date	Duration of Test Hr. Min.	Volume Cubic Meters	Wind Dir. and Velocity Mi. per Hr.	Temperature Deg. F.	Relative Humidity Per Cent	Barometric Pressure Inches	Carbon Dioxid Parts in 10,000	Filter		Milligrams per Cubic Meter					Test No.	Test Location	Remarks
									No.	Color	Solids	Nitrous Acid	Ammonia	Chlorin	Sulphuric Acid			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
4	5-31-12	18 15	30.03	SE 17	82.0	47	29.33	2.69	2	Used in No. 5	....	.00373	.00871	.1100	.0951	4	Kedzie Blvd. and Linden Pl.	
5	6- 4-12	7 50	21.57	W-NW 20	70.0	44	29.46	2.74	2	Very light	.678	.00129	.00335	.0000	.0939	5	" " " "	
110	3-31-13	5 30	22.94	W 20	54.5	49	29.16	3.04	116	Almost white	.575	.00168	.00781	.0864	.0761	110	Humboldt Bl. & Wrightwood	
2	5-23-12	14 10	21.65	W 7	78.0	50	29.21	2.73	1	Used in No. 3	...	.01014	.00910	.1689	.0262	2	Humboldt Pk. Music Court	
3	5-28-12	10 10	25.83	S-N 18	58.0	83	29.07	2.68	1	Light gray	.305	.00561	.00505	.1412	.0151	3	" " " "	
111	4- 1-13	4 45	14.30	W 16	57.8	51	29.35	2.77	117	Almost white	.069	.00159	.00765	.0847	.3570	111	" " " "	
152	6-17-13	6 25	21.85	SW-N 6	70.7	71	29.47	3.38	166	Gray	.412	.01098	.01158	.0000	.2039	152	" " " "	Night
30	7-26-12	7 40	28.33	N 12	71.0	68	29.53	2.62	25	Used in No. 31	....	.00258	.00314	.1017	.2278	30	Garfield Park	
31	7-27-12	6 45	20.62	N-E 8	79.0	53	29.56	2.51	25	Brown	.206	.00265	.01105	.1158	.3724	31	" "	
155	6-20-13	6 25	24.39	SW 13	75.0	71	29.30	3.69	169	Very light gray	.205	.00602	.01133	.0000	.0000	155	" "	Night
35	8- 2-12	7 20	23.08	NE 13	72.6	62	29.52	2.61	26A	Very light	.277	.00334	.02899	.0000	.2095	35	McKinley Pk. North Side	
153	6-18-13	6 30	24.35	N-SW 7	62.6	76	29.54	3.69	167	Dark gray	.616	.01138	.01144	.0000	.3520	153	" " " "	Night
115	4- 8-13	6 10	24.54	E-NE 15	40.8	79	29.52	3.01	121	Trace of gray	.041	.00034	.00499	0000	.0709	115	Lincoln Park near Lake	
129	5- 8-13	5 45	23.37	W-NE 8	58.5	64	29.50	3.16	129	Very light gray	.021	.00217	.00708	.0000	.0298	129	" Pk. Grant Monument	
151	6-16-13	6 05	22.28	SW 10	77.0	64	29.37	3.76	164	Very dark gray	.225	.00690	.01670	.1499	.3206	151	" " " "	Night
112	4- 2-13	6 30	23.82	SE 17	45.0	87	29.01	3.15	118	Very light gray	.008	.00048	.00606	.0000	.0809	112	Grant Park near Lake	
150	6-14-13	6 45	19.23	SW 9	70.0	54	29.37	4.06	163	Very black	.572	.01061	.00901	.2720	1.6710	150	" " " "	Night
87	1-31-13	6 45	23.74	W 26	19.1	68	29.15	4.07	91	Black, cinders	6.971	.00510	.00069	.3920	.5474	87	Monroe east of Michigan	Dirt
116	4- 9-13	6 00	24.76	E 17	40.0	96	29.27	3.15	122	Light gray	.162	.00249	.00516	.0000	.0682	116	Michigan and Congress	Wet
118	4-11-13	6 20	22.97	SW 16	46.0	80	29.14	4.11	124	Dark gray	.849	.00753	.00425	.3538	1.5240	118	Monroe east of Michigan	Wet
73	12- 3-12	6 15	25.35	S 24	36.0	86	29.29	2.57	55	Gray	.592	.00535	.00325	.1042	.2830	73	University of Chicago	
16	6-28-12	14 45	37.94	NE-W 9	74.0	67	29.52	2.44	12	Light	.483	.00328	.00724	.0708	.2330	16	Washington Park	
108	3-27-13	5 00	17.24	NW 14	27.8	77	29.47	2.99	114	Very light	.058	.00732	.00581	.0598	.3985	108	" "	Ice
17	7- 3-12	8 00	22.67	S-SW 16	81.0	68	29.47	2.46	13	Used in No. 18	....	.01101	.00861	.0000	.8041	17	Jackson Park	
18	7- 6-12	7 45	20.54	SE-E 9	80.5	78	29.48	2.71	13	Very light	.542	.00541	.01060	.0000	.1583	18	" "	
114	4- 7-13	6 05	24.82	NE 20	38.0	87	29.51	3.00	120	Almost white	121	.00041	.00528	.0000	.0410	114	" "	Lake front
19	7- 8-12	8 45	23.71	S 11	82.0	76	29.45	2.64	14	Light	675	.00256	.00602	.1750	.2054	19	Greenwood and 75th Pl.	
20	7- 9-12	8 10	20.57	SW-S 11	87.0	66	29.43	2.57	15	Very light	.486	.00556	.01060	.2106	.5260	20	Bessemer Park	
131	5-12-13	6 10	25.22	SW 20	71.5	45	29.23	3.99	141	Dark gray	1.249	.01080	.00646	2125	1.5940	131	Michigan east of Randolph	

TABLE CXVII. OBSERVED DATA AND RESULTS OF AIR ANALYSES
PLAYGROUND DISTRICTS

Test No.	Date	Duration of Test Hr. Min.	Volume Cubic Meters	Wind Dir. and Velocity Mi. per Hr.	Temperature Deg. F.	Relative Humidity Per Cent	Barometric Pressure Inches	Carbon Dioxid Parts in 10,000	Filter		Milligrams per Cubic Meter					Test No.	Test Location	Remarks
									No.	Color	Solids	Nitrous Acid	Ammonia	Chlorin	Sulphuric Acid			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
27	7-20-12	8 00	27.68	SE 8	64.0	75	29.58	2.74	22	Dark	.401	.00597	.00789	.0488	.4742	27	Vedder and Penn	Night
28	7-20-12	8 00	25.17	E 12	70.0	77	29.43	2.81	23	Light	.457	.00194	.01340	.0731	.0921	28	" " "	
82	1-13-13	6 00	17.46	S-SW 13	26.2	85	29.69	3.06	86	Gray	.200	.01212	.00494	.1489	.5428	82	14th and Jefferson	
32	7-29-12	6 25	23.76	E 8	76.5	69	29.34	2.57	26	Rather gray	.147	.00318	.00683	.0000	.1839	32	LaSalle and 26th Pl.	
33	7-30-12	6 40	23.30	W 15	82.7	55	29.29	2.64	29	Light	.279	.00693	.01357	.1576	.2740	33	29th and Halsted	
42B	8-20-12	7 35	24.90	SW-W 8	71.7	89	29.37	3.29	36	Dark	.181	.00791	.02046	.1065	.3456	42B	" " "	Night
105	3-22-13	6 15	23.76	E 7	29.0	68	29.96	3.21	110	Light gray	.147	.01065	.00129	.0612	.5890	105	Shields and 34th	
44	8-22-12	7 00	22.25	W-SW 13	63.0	87	29.15	3.16	34	Dark	.202	.00458	.02010	.0979	.2413	44	Marshfield and 45th	Night
15	6-26-12	11 15	26.94	N 15	68.5	68	29.45	2.83	11	Rather dark	.873	.01010	.01207	.1044	1.2100	15	47th and Princeton	

TABLE CXVIII. OBSERVED DATA AND RESULTS OF AIR ANALYSES
MIXED RESIDENCE DISTRICTS

Test No.	Date	Duration of Test Hr. Min.	Volume Cubic Meters	Wind Dir. and Velocity Mi. per Hr.	Temperature Deg. F.	Relative Humidity Per Cent	Barometric Pressure Inches	Carbon Dioxid Parts in 10,000	Filter		Milligrams per Cubic Meter					Test No.	Test Location	Remarks
									No.	Color	Solids	Nitrous Acid	Ammonia	Chlorin	Sulphuric Acid			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
58	10- 2-12	7 00	19.48	SW 15	68.5	45	29.59	2.92	52	Rather dark	.914	.00470	.00486	.0405	.6357	58	Diversey Blvd. and Paulina	
113	4- 5-13	6 00	23.14	W-NW 12	51.0	59	29.50	3.19	119	Rather gray	.938	.00396	.00351	.1446	.4501	113	Carroll and Wood	
101	3-17-13	4 30	8.71	S-SE 14	29.6	64	29.83	3.41	105	Gray	.374	.02726	.00290	.0000	1.8420	101	Ohio and Morgan	
121	4-24-13	5 45	20.40	S 25	72.0	62	29.26	3.28	132	Gray	2.304	.00891	.01142	.1517	.6254	121	Austin and Hoyne	
81	12-16-12	6 20	15.73	E-SE 10	40.0	89	29.28	3.30	81	Gray	.381	.01228	.00260	.2825	1.0090	81	Austin and Ashland	
69	11- 9-12	6 10	19.58	NW-W 6	47.0	63	29.58	3.02	69	Rather dark	1.047	.01066	.00994	.0544	.3742	69	Wade and Crittenden	
51	8-28-12	6 35	23.93	S 18	63.0	71	29.37	3.31	50		.326	.00674	.00716	.0000	.2461	51	Oakley and 18th	Night
13	6-19-13	8 15	21.07	NW-W 12	68.0	55	29.38	2.76	8	Light gray	.527	.00443	.01047	.0818	.3090	13	Jefferson north of 21st	
42B	8-20-12	7 35	24.90	SW-W 8	71.7	89	29.37	3.29	36	Dark	.181	.00791	.02046	.1065	.3456	42B	Halsted and 29th	Night
33	7-30-12	6 40	23.30	W 15	82.7	55	29.29	2.64	29	Light	.279	.00693	.01357	.1576	.2740	33	" " "	
75	12- 5-12	6 05	21.69	S 15	55.0	91	29.12	3.11	54	Rather dark	1.822	.01069	.01042	.1879	.6130	75	Armour and 37th	
14	6-20-12	11 45	25.96	SW-NE 13	70.5	61	29.42	2.74	7	Dark	.428	.00348	.01104	.0989	.2265	14	Dearborn and 36th	
45	8-23-12	7 35	22.45	W 9	59.5	84	29.25	3.32	40		.178	.00457	.00947	.2291	.1492	45	Union and 50th	Night
46	8-23-12	8 00	23.32	W-NW 11	69.0	62	29.36	3.20	44		.129	.00490	.01374	.2398	.3585	46	" " "	
126	5- 5-13	5 45	21.67	S 14	70.0	75	29.63	3.51	130	Dark gray	.554	.00573	.01985	.0000	.3151	126	Emerald and 39th	Rain
43	8-21-12	7 00	24.99	W 8	71.0	82	29.34	3.37	32	Very dark gray	.127	.00627	.05194	.0694	.8247	43	" " 46th	Night
74	12- 4-12	6 25	19.36	SW-SE 6	42.0	85	29.30	2.95	73	Dark	1.007	.01401	.00647	.1188	.5800	74	Shields and 44th	
15	6-26-12	11 15	26.94	N 15	68.5	68	29.45	2.83	11	Rather dark	.873	.01010	.01207	.1044	1.2100	15	Princeton and 47th	
107	3-26-13	6 30	20.88	N 15	27.1	88	29.27	3.13	113	Dark gray	.335	.01848	.00321	.0874	.8168	107	Shields and 53d	
80	12-13-12	6 35	21.55	SW 18	40.0	58	29.45	3.01	80	Dark gray	2.413	.00395	.00296	.2358	.7700	80	" " "	R.R smoke
127	5- 6-13	5 45	17.18	NE 9	56.3	65	29.63	3.49	131	Very dark	.291	.00517	.00748	.4855	1.0070	127	55th Blvd. and Normal	
145	6- 9-13	6 15	22.50	NE 13	51.0	69	29.83	..	158	Very black	.222	.00386	.00610	.3699	1.0252	145	" " " "	Night
77	12- 9-12	6 50	18.51	SW 22	28.0	58	29.44	2.89	74	Gray	1.809	.00544	.00239	.1080	.4893	77	Princeton and 28th	
20	7- 9-12	8 10	20.57	SW-S 11	87.0	66	29.43	2.57	15	Very light	.486	.00556	.01060	.2106	.3260	20	Bessemer Park, east side	Rain
134	5-16-13	6 20	19.43	E 9	58.0	68	29.33	3.34	144	Gray	2.316	.00418	.00750	.1030	.0190	134	90th and Mackinaw	

TABLE CXIX. OBSERVED DATA AND RESULTS OF AIR ANALYSES
LOOP DISTRICT

Test No.	Date	Duration of Test Hr. Min.	Volume Cubic Meters	Wind Dir. and Velocity Mi. per Hr.	Temperature Deg. F.	Relative Humidity Per Cent	Barometric Pressure Inches	Carbon Dioxid Parts in 10,000	Filter		Milligrams per Cubic Meter					Test No.	Test Location	Remarks
									No.	Color	Solids	Nitrous Acid	Ammonia	Chlorin	Sulphuric Acid			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
131	5-12-13	6 10	25.22	SW 20	71.5	45	29.23	3.99	141	Dark gray	1.249	.01080	.00646	.2125	1.5940	131	Michigan and Randolph	
87	1-31-13	6 45	23.74	W 26	19.1	68	29.15	4.07	91	Black, cinders	6.971	.00510	.00069	.3920	.5474	87	Monroe east of Michigan	Dirt
118	4-11-13	6 20	22.97	SW 16	46.0	80	29.14	4.11	124	Dark gray	.849	.00753	.00425	.3538	1.5240	118	" " " "	Ground wet
144	6- 7-13	7 25	25.15	N 28	47.0	79	29.48	3.11	155	Light gray	1.411	.00297	.00335	.0000	.7112	144	" " " "	Night
116	4- 9-13	6 00	24.76	E 17	40.0	96	29.27	3.15	122	Light gray	.162	.00249	.00516	.0000	.0682	116	Michigan and Congress	Raining
95	2-15-13	6 25	18.28	SW-W 18	41.0	74	28.98	3.93	99	Gray	1.750	.01555	.00531	.3754	.9505	95	Dearborn south of Lake	
103	3-19-13	5 20	11.95	S 29	64.3	49	29.23	4.03	107	Dirty white	2.078	.05754	.00642	.1278	3.2100	103	" " " "	
90	2- 6-13	6 25	18.81	W 15	18.9	57	29.30	4.31	94	Dark and dirty	3.211	.01203	.00104	.4033	.5689	90	Randolph east of Dearborn	
94	2-13-13	6 15	19.28	SW 22	23.0	60	29.47	4.41	98	Black paper	9.257	.01296	.00286	.6775	1.5910	94	Washington west of Dearborn	St. debris
117	4-10-13	5 50	23.00	S 17	62.0	70	28.99	4.36	123	Dark gray	.687	.01719	.01037	.2521	1.2660	117	" " " "	Street wet
140	6- 3-13	6 15	20.01	W 10	68.5	61	29.23	3.73	152	Dark gray	.625	.00887	.01193	.2780	.2232	140	Dearborn north of Madison	Night
99	2-21-13	6 30	19.46	NE-E 21	34.0	92	29.20	3.75	103	Almost white	.411	.01855	.00379	.0000	.6939	99	" " " Adams	Raining
139	6- 2-13	6 05	24.30	NE 7	58.0	70	29.42	3.12	151	Dark gray	.165	.00639	.00068	.0000	.0680	139	" " " "	Night
102	3-18-13	6 20	18.53	S 31	57.2	44	29.54	3.61	106	Dirty gray	7.377	.02552	.00384	.2622	2.3690	102	" " " "	
141	6- 4-13	6 10	22.97	N 10	55.0	77	29.46	3.64	150	Light gray	1.198	.00721	.00094	.0602	.5267	141	" and Polk	Night
158	6-24-13	6 20	23.90	S 16	82.0	67	29.23	3.59	172	Gray	2.050	.01355	.01806	.0564	.5525	158	Plymouth Court and Polk	St. debris
89	2- 5-13	6 30	21.30	W 16	11.6	71	29.39	3.85	83	Dirty, dark	3.733	.04021	.00131	.4481	.7388	89	Clark south of Adams	
104	3-20-13	6 15	20.96	SW-W 20	40.5	72	29.19	3.74	109	Dirty gray	1.598	.02368	.00432	.0554	1.9550	104	" " " "	
138	5-30-13	6 10	23.86	N-NE 12	64.5	78	29.28	3.76	149	Gray	.922	.01299	.01120	.1359	.6620	138	" " " "	Mem'l Day
156	6-21-13	6 00	25.10	N 9	61.6	95	29.31	3.40	170	Very light gray	.040	.01322	.00975	.0000	.0239	156	" " " "	Night
96	2-16-13	6 05	13.75	SW 9	31.2	77	29.16	3.38	100	Gray	.982	.01513	.00374	.3415	.7544	96	" " " Van Buren	Sunday
97	2-17-13	6 10	19.84	NE-E 9	33.6	76	29.33	3.88	101	Gray	.706	.01764	.00525	.1512	.6346	97	" " " " "	
55	9-23-12	7 45	23.64	S-SE 9	60.5	53	29.51	3.80	45	Dark	.867	.01003	.00930	.2375	2.2070	55	Lake and La Salle	
100	3-10-13	6 10	21.07	E 6	33.6	88	29.36	3.69	104	Very light gray	.095	.02262	.00324	.0000	.7311	100	Lake near 5th Ave.	
106	3-24-13	6 15	19.21	W 14	47.6	76	29.20	3.56	111	Very light gray	.521	.02910	.00754	.1397	.8600	106	Lake west of La Salle	
143	6- 6-13	6 15	20.81	S 17	72.0	61	29.31	3.52	154	Gray	.360	.00796	.01209	.2142	.6040	143	" " " "	
91	2- 8-13	6 25	21.72	NW-W 12	29.0	55	29.36	4.08	95	Gray	1.496	.00831	.00179	.3010	1.0230	91	La Salle bet. Adams and Monroe	
92	2- 9-13	6 20	21.82	W 7	29.5	66	29.51	3.57	96	Dark gray	.458	.00922	.00102	.2416	.6723	92	" " " " "	Sunday
93	2-10-13	6 05	15.67	S 16	33.6	75	29.35	4.11	97	Very dark gray	1.915	.01755	.00522	.3175	2.0470	93	" " " " "	
142	6- 5-13	6 30	21.76	SE 12	63.6	68	29.51	3.42	153	Very dark gray	1.034	.01004	.00951	.1023	.4170	142	" " " " "	Night
133	5-14-13	6 00	21.91	NE 16	53.8	82	29.34	3.71	143	Gray	.365	.00822	.00592	.1650	.0252	133	Monroe and Canal	
122	4-25-13	5 55	23.82	NW-N 7	46.0	91	29.45	3.19	134	Gray	.168	.00782	.00382	.0947	.9224	122	Canal south of Randolph	Rain
98	2-20-13	6 25	20.97	NW-N 9	40.0	80	29.25	3.76	102	Gray	.429	.01766	.01282	.1878	.5373	98	Market near Monroe	

TABLE CXX. OBSERVED DATA AND RESULTS OF AIR ANALYSES
BOULEVARD DISTRICTS

Test No.	Date	Duration of Test Hr. Min.	Volume Cubic Meters	Wind Dir. and Velocity Mi. per Hr.	Temperature Deg. F.	Relative Humidity Per Cent	Barometric Pressure Inches	Carbon Dioxid Parts in 10,000	Filter		Milligrams per Cubic Meter					Test No.	Test Location	Remarks
									No.	Color	Solids	Nitrous Acid	Ammonia	Chlorin	Sulphuric Acid			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
116	4- 9-13	6 00	24.76	E 17	40.0	96	29.27	3.15	122	Light gray	.162	.00249	.00516	.0000	.0682	116	Michigan and Congress	Raining
87	1-31-13	6 45	23.74	W 26	19.1	68	29.15	4.07	91	Black, cinders	6.971	.00510	.00069	.3920	.5474	87	Monroe east of Michigan	Dirt
118	4-11-13	6 20	22.97	SW 16	46.0	80	29.14	4.11	124	Dark gray	.849	.00753	.00425	.3538	1.5240	118	" " " "	
58	10- 2-12	7 00	19.48	SW 15	68.5	45	29.59	2.92	52	Rather dark	.913	.00470	.00486	.0405	.6357	58	Diversey and Paulina	
84	1-17-13	6 00	20.34	W 13	43.3	66	29.21	3.44	85	Light gray	.374	.00963	.00402	.1682	.5560	84	Augusta and Oakley	
29	7-25-12	7 00	23.05	NW 15	87.0	46	29.36	2.52	24	Light	1.150	.00227	.01107	.0960	.2460	29	Washington and Talman	
42A	8-19-12	6 10	22.77	SW 15	70.0	91	29.38	3.11	39	Very light	.119	.00461	.02634	.1620	.7380	42A	" " "	Night
37	8- 6-12	7 00	24.44	S 12	77.0	49	29.53	2.86	30	Brown	1.575	.00934	.02847	.1315	.4700	37	" " Halsted	
12	6-17-12	11 00	25.45	NW-SE 10	64.0	58	29.45	2.89	9	Little gray	.432	.01101	.01089	.1248	.6520	12	" " Desplaines	
23	7-13-12	8 05	26.61	SW 18	75.0	82	29.28	2.87	18a	Rather gray	.748	.00597	.01983	.0983	.4041	23	" " "	Night
79	12-11-12	6 25	24.54	NW-W 17	18.0	68	29.50	2.88	75	Light gray	1.324	.00310	.00221	.0649	.1871	79	67th Bl. and Prairie	
127	5- 6-13	5 45	17.18	NE 9	56.3	65	29.63	3.49	131	Very dark	.291	.00517	.00748	.1855	1.6070	127	55th Bl. and Normal	
145	6- 9-13	6 15	22.50	NE 13	51.0	69	29.83	....	158	Very black	.222	.00386	.00616	.3699	1.0252	145	" " " "	Night
52	8-29-12	8 45	26.43	NE 11	65.0	87	29.41	3.43	57		.189	00239	.01059	.0605	.0929	52	Sacramento and Chicago	Night
144	6- 7-13	7 25	25.15	N 28	47.0	79	29.48	3.11	155	Light gray	1.411	.00297	.00335	.0000	.7112	144	Monroe east of Michigan	Night

TABLE CXXI. OBSERVED DATA AND RESULTS OF AIR ANALYSES
INDUSTRIAL DISTRICTS

Test No.	Date	Duration of Test Hr. Min.	Volume Cubic Meters	Wind Dir. and Velocity Mi. per Hr.	Temperature Deg. F.	Relative Humidity Per Cent	Barometric Pressure Inches	Carbon Dioxid Parts in 10,000	Filter		Milligrams per Cubic Meter					Test No.	Test Location	Remarks
									No.	Color	Solids	Nitrous Acid	Ammonia	Chlorin	Sulphuric Acid			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
60	10-25-12	6 05	24.90	N 7	56.6	65	29.42	2.80	56	Light gray	.347	.00390	.00444	.0599	.4561	60	Com'wealth Ed'n N.W. Plant	
61	10-26-12	6 35	24.12	SW-W 8	61.0	45	29.44	2.94	56	Used in No. 60	.....	.00223	.00648	.0000	.2525	61	" " "	
63	10-30-12	5 35	16.21	E 7	46.0	67	29.50	2.97	65	Gray	.432	.00338	.00601	.0500	.4548	63	Clybourne Pl. and Southport	
68	11- 8-12	6 45	24.22	W 29	51.5	50	29.23	2.73	68	Dark gray	3.282	.00702	.00346	.0743	.5179	68	Division and Hickory	
26	7-18-12	7 55	25.10	E-NE 9	69.4	66	29.59	3.05	21	Medium	.928	.00389	.01132	.0000	.2336	26	Illinois west of Orleans	
24	7-16-12	7 45	27.23	NE 16	58.0	86	29.66	2.64	19	Light	.279	.00279	.01107	.0357	.0517	24	" " " "	Night
59	10-14-12	6 30	17.73	SW 19	63.5	43	29.52	3.34	59	Quite dark	1.297	.00696	.00662	.1896	.6127	59	Hawthorne west of Larrabee	
101	3-17-13	4 30	8.71	S-SE 14	29.6	64	29.83	3.41	105	Gray	.574	.02726	.00289	.0000	1.8420	101	Ohio and Morgan	
113	4- 5-13	6 00	23.14	W-NW 12	51.0	59	29.50	3.19	119	Rather gray	.938	.00396	.00351	.1446	.4501	113	Carroll and Wood	Street debris
121	4-24-13	5 45	20.40	S 25	72.0	62	29.26	3.28	132	Gray	2.304	.00891	.01142	.1517	.6254	121	Austin and Hoyne	
71	11-13-12	6 00	22.63	NW-W 20	41.2	84	29.12	2.97	71	Gray	.221	.00421	.00383	.1480	.3845	71	California and Fulton	
37	8- 6-12	7 00	24.44	S 12	77.0	49	29.53	2.73	30	Brown	1.575	.00934	.02847	.1315	.3700	37	Washington and Halsted	
12	6-17-12	11 00	25.45	NW-SE 10	64.0	58	29.45	2.89	9	Slightly gray	.432	.01101	.01089	.1248	.6520	12	" " Desplaines	
23	7-13-12	8 05	26.61	SW 18	75.0	82	29.28	2.87	18a	Rather gray	.748	.00597	.01983	.0983	.4011	23	" " "	Night
119	4-15-13	6 30	22.02	NE 7	53.0	46	29.28	3.50	126	Dirty black	2.611	.00862	.00455	.4504	2.1170	119	Harrison and Desplaines	
146	6-10-13	6 45	25.52	NE 5	53.3	73	29.92	3.62	157	Dark gray	.313	.00812	.01637	.1083	.7554	146	Congress and Desplaines	Night
49	8-27-12	7 15	23.49	NE 13	62.0	72	29.60	3.24	58		.192	.00452	.00621	.1098	.1284	49	16th west of Washtenaw	Night
50	8-27-12	7 15	23.25	NE 11	67.0	59	29.64	3.46	51		.194	.00335	.00731	.1686	.3576	50	" " "	
36	8- 5-12	6 45	21.54	NE-E 8	69.0	56	29.68	2.67	31	Very light	.348	.00314	.02150	.0676	.1267	36	Poplar off Archer	
34	8- 1-12	6 05	23.50	SW 9	78.6	56	29.44	2.57	28	Filter burned	....	.00218	.02105	.0000	.2565	34	Loomis south of 22d	
13	6-19-12	8 15	21.07	NW-W 12	68.0	55	29.38	2.76	8	Light gray	.527	.00443	.01047	.0818	.3090	13	Jefferson north of 21st	
126	5- 5-13	5 45	21.67	S 14	70.0	75	29.63	3.51	130	Dark gray	.554	.00573	.01985	.0000	.3151	126	Emerald and 39th	Rain
47	8-24-12	7 45	24.42	SW 16	66.5	75	29.37	3.15	48		.143	.00430	.01380	.1403	.1551	47	" " 41st	Night
86	1-22-13	7 00	19.95	S 14	34.8	64	29.47	4.00	84	Rather black	.251	.01859	.00406	.2101	.6426	86	Halsted and 43d	
43	8-21-12	7 00	21.99	W 8	71.0	82	29.34	3.37	32	Very dark	.127	.00627	.05194	.0694	.8247	43	Emerald and 46th	Night
45	8-23-12	7 35	22.45	W 9	59.5	84	29.25	3.32	40		.178	.00457	.00947	.2291	.1492	45	Union and 50th	Night
46	8-23-12	8 00	23.32	W-NW 11	69.0	62	29.36	3.20	44		.129	.00490	.01374	.2398	.3585	46	" " "	
85	1-20-13	6 35	19.44	NW 19	24.1	90	29 33	4.23	88	Very black	2.016	.00756	.00359	.3665	2.0760	85	47th near Center	Cinders
44	8-22-12	7 00	22.25	W-SW 13	63.0	87	29.15	3.16	34	Dark	.202	.00458	.02010	.0979	.2413	44	Marshfield and 45th	Night
128	5- 7-13	6 00	23.17	E-NE 8	60.5	48	29.58	3.51	133	Dirty gray	.798	.00537	.06160	.2460	.4308	128	42d east of Ashland	
19	7- 8-12	8 45	23.71	S 11	82.0	76	29.45	2.64	14	Light	.675	.00256	.00602	.1750	.2054	19	Greenwood and 75th Place	
134	5-16-13	6 20	19.43	E 9	56.6	68	29.33	3.34	144	Gray	2.316	.00418	.00750	.1030	.0190	134	Mackinaw and 90th	
58	10- 2-12	7 00	19.48	SW 15	68.5	45	29.59	2.92	52	Rather dark	.913	00470	.00486	.0405	.6357	58	Diversey Blvd. and Paulina	
157	6-23-13	6 15	22.87	E 8	75.4	65	29.27	3.39	177	Light gray	.350	.01221	.01608	.1338	.0000	157	Congress east of Center	
147	6-11-13	6 15	22.55	SE-S 5	56.0	67	29.77	4.72	159	Very black	1.064	.01191	.05256	.1435	.7014	147	" " " "	Night

TABLE CXXII. OBSERVED DATA AND RESULTS OF AIR ANALYSES
DAY AND NIGHT TESTS

Test No.	Date	Duration of Test		Volume Cubic Meters	Wind Dir. and Velocity Mi. per Hr.		Temperature Deg. F.	Relative Humidity Per Cent	Barometric Pressure Inches	Carbon Dioxid Parts in 10,000	Filter		Milligrams per Cubic Meter					Test No.	Test Location	Remarks
		Hr.	Min.								No.	Color	Solids	Nitrous Acid	Ammonia	Chlorin	Sulphuric Acid			
1	2	3		4	5		6	7	8	9	10	11	12	13	14	15	16	17	18	19
10	6-13-12	7	30	17.71	NE	14	63.0	74	29.31	2.65	5	Light gray	1.085	.01090	.01532	.0000	.7428	10	Ohio and Peoria	
11	6-14-12	7	45	22.31	E	13	65.0	80	29.01	2.96	10	Dark	.645	.00645	.01235	.1371	.8492	11	" " "	Rain
21	7-11-12	8	10	23.02	N	8	70.0	87	29.42	2.89	16	Very dark	.886	.01008	.02873	.0633	.5966	21	" " "	Night
78	12-10-12	6	05	15.56	SW-W	22	39.0	67	29.09	3.00	78	Light gray	1.414	.00761	.00606	.0000	.4315	78	44th and Ingleside	
149	6-13-13	6	20	18.23	W	10	74.0	66	29.46	3.96	162	Very black	.850	.01134	.02470	.3090	1.6170	149	42d Pl. and St. Lawrence	Night
12	6-17-12	11	00	25.45	NW-SE	10	64.0	58	29.45	2.89	9	Slightly gray	.432	.01101	.01089	.1248	.6520	12	Washington and Desplaines	
23	7-13-12	8	05	26.61	SW	18	75.0	82	29.28	2.87	18A	Rather gray	.748	.00597	.01983	.0983	.4041	23	" " " "	Night
29	7-25-12	7	00	23.05	NW	15	87.0	46	29.36	2.52	24	Light	1.150	.00227	.01107	.0960	.2460	29	" " " Talman	
42A	8-19-12	6	10	22.77	SW	15	70.0	91	29.38	3.11	39	Very light	.119	.00461	.02634	.1620	.7380	42A	" " " "	Night
50	8-27-12	7	15	23.25	NE	11	67.0	59	29.64	3.46	51		.194	.00335	.00731	.1686	.3576	50	16th west of Washtenaw	
49	8-27-12	7	15	23.49	NE	13	62.0	72	29.60	3.24	58		.192	.00452	.00621	.1098	.1284	49	" " " "	Night
26	7-18-12	7	55	25.10	E-NE	9	69.4	66	29.59	3.05	21	Medium	.928	.00389	.01132	.0000	.2336	26	Illinois west of Orleans	
24	7-16-12	7	45	27.23	NE	16	58.0	86	29.66	2.64	19	Light	.279	.00279	.01107	.0357	.0517	24	" " " "	Night
157	6-23-13	6	15	22.87	E	8	75.4	65	29.27	3.39	177	Light gray	.350	.01221	.01608	.1338	.0000	157	Congress east of Center	
147	6-11-13	6	15	22.55	SE-S	5	56.0	67	29.77	4.72	159	Very black	1.064	.01191	.05256	.1435	.7014	147	" " " "	Night
119	4-15-13	6	30	22.02	NE	7	53.0	46	29.28	3.50	126	Dirty black	2.611	.00862	.00455	.4504	2.1170	119	Harrison and Desplaines	
146	6-10-13	6	45	25.52	NE	5	53.3	73	29.92	3.62	157	Dark gray	.313	.00812	.01637	.1083	.7554	146	Congress and Desplaines	Night
47	8-24-12	7	45	24.42	SW	16	66.5	75	29.37	3.15	48		.143	.00430	.01380	.1403	.1551	47	Emerald and 41st	Night
86	1-22-13	7	00	19.95	S	14	34.8	64	29.47	4.00	84	Rather black	.251	.01859	.00406	.2101	.6426	86	Halsted and 43d	
44	8-22-12	7	00	22.25	W-SW	13	63.0	87	29.15	3.16	34	Dark	.202	.00453	.02010	.0979	.2413	44	Marshfield and 45th	Night
43	8-21-12	7	00	21.99	W	8	71.0	82	29.34	3.37	32	Very dark	.127	.00627	.05194	.0694	.8247	43	Emerald and 46th	Night
46	8-23-12	8	00	23.32	W-NW	11	69.0	62	29.36	3.20	44		.129	.00490	.01374	.2398	.3585	46	Union and 50th	
45	8-23-12	7	35	22.45	W	9	59.5	84	29.25	3.32	40		.178	.00457	.00947	.2291	.1492	45	" " "	Night
1	5-20-12	6	25	7.48	SW-N	17	69.0	69	29.31	3.25	X	Light	6.290	.01976	.01336	.6210	....	1	Clark and 12th	Rain
25	7-17-12	7	25	25.38	NE	8	62.5	76	29.56	2.77	20	Rather dark	.985	.00784	.00497	.0739	.5570	25	" " "	Night
141	6- 4-13	6	10	22.97	N	10	55.0	77	29.46	3.64	150	Light gray	1.198	.00721	.00094	.0602	.5267	141	Dearborn and Polk	Night
158	6-24-13	6	20	23.90	S	16	82.0	67	29.23	3.59	172	Gray	2.050	.01355	.01806	.0564	.5525	158	Plymouth Court and Polk	
54	8-30-12	7	00	18.29	S	11	77.6	72	29.40	3.31	53	Dark	1.121	.00970	.01275	.0682	1.8510	54	Kinsie and Clinton	
53	8-30-12	8	10	28.35	SE	15	66.0	83	29.47	3.49	42	Very dark	.829	.00511	.00614	.0467	.7237	53	" " "	Night
109	3-28-13	6	15	24.84	S	27	41.0	68	29.47	3.39	115	Dark gray	1.710	.00916	.00479	.1181	1.8530	109	Kinsie and Canal	
41	8-17-12	7	45	20.80	S-SW	16	87.6	62	29.44	3.17	38	Dark	1.658	.00672	.01503	.0560	.8882	41	Austin and Artesian	
40	8-17-12	8	00	26.70	SE	13	68.0	75	29.55	3.08	37	Very dark	.554	.00825	.01130	.1204	.9640	40	" " "	Night
71	11-13-12	6	00	22.63	NW-W	20	41.2	84	29.12	2.97	71	Gray	.221	.00421	.00383	.1480	.3845	71	California and Fulton	
52	8-29-13	6	45	26.43	NE	11	65.0	87	29.41	3.43	57		.189	.00239	.01059	.0605	.0929	52	Sacramento and Chicago	Night
48	8-26-12	7	45	26.69	SW	15	73.0	82	29.25	2.79	43		.019	.00428	.01989	.0000	.0953	48	14th and Western	Night
88	2- 1-13	6	35	20.02	W	16	9.0	78	29.68	3.51	92	Dark	1.898	.00871	.00211	.1105	.3576	88	17th and Robey	
51	8-28-12	6	35	23.93	S	18	63.0	71	29.37	3.31	50		.326	.00674	.00716	.0000	.2461	51	18th and Oakley	Night
127	5- 6-13	5	45	17.18	NE	9	56.3	65	29.63	3.49	131	Very dark	.291	.00517	.00748	.1855	1.6070	127	55th Bl. and Normal	
145	6- 9-13	6	15	22.50	NE	13	51.0	69	29.83	....	158	Very black	.222	.00386	.00616	.3699	1.0252	145	" " " "	Night
94	2-13-13	6	15	19.28	SW	22	23.0	60	29.47	4.41	98	Black paper	9.257	.01296	.00286	.6775	1.5910	94	Washington west of Dearborn	
117	4-10-13	5	50	23.00	S	17	62.0	79	28.99	4.36	123	Dark gray	.687	.01719	.01037	.2521	1.2660	117	" " " " "	Street wet
140	6- 3-13	6	15	20.01	W	10	68.5	63	29.23	3.73	152	Dark gray	.625	.00887	.01193	.2780	.2232	140	Dearborn north of Madison	Night
99	2-21-13	6	30	19.46	NE-E	21	34.0	92	29.26	3.75	103	Almost white	.411	.01855	.00379	.0000	.6999	98	" " " Adams	Street wet
102	3-18-13	6	20	18.53	S	31	57.2	44	29.54	3.61	106	Dirty gray	7.377	.02552	.00384	.2622	2.3690	102	" " " "	
139	6- 2-13	6	05	24.30	NE	7	58.0	70	29.42	3.12	151	Dark gray	.165	.00639	.00066	.0000	.3680	139	" " " "	Night
89	2- 5-13	6	30	21.30	W	16	11.6	71	29.39	3.85	83	Dirty, dark	3.733	.01021	.00131	.4481	.7388	89	Clark south of Adams	
104	3-20-13	6	15	20.96	SW-W	20	40.5	72	29.19	3.74	109	Dirty gray	1.598	.02366	.00432	.0554	1.9550	104	" " " "	
138	5-30-13	6	10	23.86	N-NE	12	64.5	78	29.28	3.76	149	Gray	.922	.01299	.01120	.1359	.6620	138	" " " "	Mem'l Day
156	6-21-13	6	00	25.10	N	9	61.6	95	29.34	3.40	170	Very light gray	.040	.01322	.00975	.0000	.0239	156	" " " "	Night, rain
55	9-23-12	7	45	23.64	S-SE	9	60.5	53	29.51	3.89	45	Dark	.867	.01063	.00930	.2375	2.2070	55	LaSalle near Lake	
100	3-10-13	6	10	21.07	E	6	33.6	88	29.36	3.69	104	Very light gray	.095	.02262	.00324	.0000	.7311	100	Lake near 5th Ave.	
106	3-24-13	6	15	19.21	W	14	47.6	76	29.20	3.56	111	Very light	.521	.02940	.00754	.1397	.8600	106	" " LaSalle	
143	6- 6-13	6	15	20.81	S	17	72.0	61	29.31	3.52	154	Gray	.360	.00796	.01209	.2142	.6040	143	" " "	Night
91	2- 8-13	6	25	21.72	NW-W	12	29.0	55	29.36	4.08	95	Gray	1.496	.00831	.00179	.3010	1.0230	91	LaSalle north of Adams	
92	2- 9-13	6	20	21.82	W	7	29.5	66	29.51	3.57	96	Dark gray	.458	.00922	.00102	.2416	.6723	92	" " " "	Sunday
93	2-10-12	6	05	15.67	S	16	33.6	75	29.35	4.11	97	Very dark gray	1.915	.01755	.00522	.5175	2.0170	93	" " " "	
142	6- 5-13	6	30	21.76	SE	12	63.6	68	29.51	3.42	153	Very dark gray	1.034	.01004	.00951	.1025	.4170	142	" " " "	Night
39	8-16-12	7	45	20.01	NE	11	63.0	70	29.64	2.68	35	Very light	.100	.00306	.01502	.0705	.2317	39	Princeton and 53d	Night
38	8-15-12	7	45	26.49	NE	16	68.0	73	29.63	2.80	33	Rather light	.691	.00405	.00881	.0988	.6424	38	Lowe and 56th	
2	5-23-12	14	10	21.65	W	7	78.0	50	29.21	2.73	1	Used in No. 3	....	.01014	.00910	.1689	.0262	2	Humboldt Park Music Court	
3	5-28-12	10	10	25.83	S-N	18	58.0	83	29.07	2.68	1	Light gray	.305	.00561	.00504	.1412	.0151	3	" " " "	
111	4- 1-13	4	45	14.30	W	16	57.8	51	29.35	2.77	117	Almost white	.070	.00160	.00765	.0847	.3570	111	" " " "	
152	6-17-13	6	25	21.85	SW-N	6	70.7	74	29.47	3.38	166	Gray	.412	.01098	.01158	.0000	.2030	152	" " " "	Night
30	7-26-12	7	40	28.33	N	12	71.0	68	29.53	2.62	25	Used in No 31	....	.00258	.00314	.1017	.2278	30	Garfield Park	
31	7-27-12	6	45	20.62	N-E	8	79.0	53	29.56	2.51	25	Brown	.206	.00265	.01105	.1158	.3724	31	" "	
155	6-20-13	6	25	24.39	SW	13	75.0	71	29.30	3.69	169	Very light gray	.205	.00802	.01103	.0000	.0000	155	" "	Night
35	8- 2-12	7	20	23.08	NE	13	72.6	62	29.52	2.61	26A	Very light	.277	.00334	.02890	.0000	.2095	35	McKinley Park, North Side	
153	6-18-13	6	20	24.35	N-SW	7	62.6	76	29.54	3.69	167	Dark gray	.616	.01138	.01144	.0000	.3520	153	" " " "	Night
33	7-30-12	6	40	23.20	W	15	82.7	55	29.29	2.64	29	Light	.279	.00693	.01357	.1576	.2740	33	Halsted and 29th	
42B	8-20-12	7	35	24.90	SW-W	8	71.7	89	29.37	3.29	36	Dark	.181	.00791	.02046	.1065	.3456	42B	" " "	Night
87	1-31-13	6	45	23.74	SW	26	19.1	68	29.15	4.07	91	Black, cinders	6.971	.00510	.00069	.3920	.5474	87	Monroe east of Michigan	Dirt

TABLE CXXII (Continued). OBSERVED DATA AND RESULTS OF AIR ANALYSES
DAY AND NIGHT TESTS

Test No.	Date	Duration of Test Hr. Min.	Volume Cubic Meters	Wind Dir. and Velocity Mi. per Hr.	Temperature Deg. F.	Relative Humidity Per Cent	Barometric Pressure Inches	Carbon Dioxid Parts in 10,000	Filter		Milligrams per Cubic Meter					Test No.	Test Location	Remarks
									No.	Color	Solids	Nitrous Acid	Ammonia	Chlorin	Sulphuric Acid			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
118	4-11-13	6 20	22.97	SW 16	46.0	80	29.14	4.11	124	Dark gray	.849	.00753	.00125	3538	1.5240	118	Monroe east of Michigan	
144	6- 7-13	7 25	25.15	N 28	47 0	79	29.48	3.11	155	Light gray	1.411	.00297	.00335	0000	.7112	144	" " " "	Night
112	4- 2-13	6 30	23.82	SE 17	45.0	87	29.01	3 15	118	Very light gray	.008	.00018	.00603	.0000	.0809	112	Grant Park on Lake Front	
150	6-14-13	6 45	19.23	SW 9	70 0	54	29.37	4.06	163	Very black	.572	.01061	.00901	.2720	1.6710	150	" Pk. bet. Lake and R. R.	Night
129	5- 8-13	5 45	23.37	W-NE 8	58.5	64	29.50	3.16	129	Very light gray	.021	.00217	.00708	.0000	.0298	129	Lincoln Pk. Grant Monument	
151	6-16-13	6 05	22.28	SW 10	77 0	64	29.37	3.76	164	Very dark gray	.225	.00690	.01670	.1499	.3206	151	" " "	Night
28	7-20-12	8 00	25.17	E 12	70 0	77	29.43	2.81	23	Rather light	.457	.00194	.01340	.0731	.0921	28	Vedder and Penn	
27	7-20-12	8 00	27.68	SE 8	64.0	75	29.58	2.74	22	Dark	.401	.00597	.00789	.0488	.4742	27	" " "	Night
120	4-18-13	6 25	25.41	W 17	69.5	47	29.27	3.19	127	Light gray	.787	.00185	.00663	.0856	.0555	120	Ashland and Wilson	
154	6-19-13	6 10	25 19	S-SW 14	73.3	70	29.44	3.54	168	Light gray	.138	.00822	.01610	.0936	.0000	154	" " Montrose	Night
65	11- 1-12	6 00	23.91	NW 8	38.0	59	29.39	2.98	66	Used in No. 66	. . . .	.00408	.00343	.0452	.2560	65	Racine and Belden	
66	11- 5-12	6 00	20 56	S 8	56.6	78	29.32	2.66	66	Dark gray	.405	.00810	.00731	.2042	.8107	66	" " Huber	
148	6-12-13	6 45	19.22	W 9	56 0	69	29.62	3.91	160	Black	.468	.01375	.01846	.1362	.4841	148	" " Fullerton	Night
9	6- 1-12	9 30	26 59	SW-N 14	75 0	46	29.48	2.57	4	Gray	.944	.00502	.00681	.0474	.3172	9	Emily and Paulina	
22	7-12-12	7 45	22 70	SE 7	71 0	75	29 39	3 14	17	Rather dark	427	.01343	.05322	.1502	5490	22	" " "	Night

TABLE CXXIII. OBSERVED DATA AND RESULTS OF AIR ANALYSES
RESIDENCE DISTRICTS

Test No.	Date	Duration of Test Hr. Min.	Volume Cubic Meters	Wind Dir. and Velocity Mi. per Hr.	Temperature Deg. F.	Relative Humidity Per Cent	Barometric Pressure Inches	Carbon Dioxid Parts in 10,000	Filter		Milligrams per Cubic Meter					Test No.	Test Location	Remarks
									No.	Color	Solids	Nitrous Acid	Ammonia	Chlorin	Sulphuric Acid			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
120	4-18-13	6 25	25.41	W 17	69.5	47	29.27	3.19	127	Light gray	.787	.00185	.00663	.0856	.0555	120	Wilson and Ashland	
154	6-19-13	6 10	25.19	S-SW 14	73.3	70	29.44	3 54	168	Light gray	.138	.00822	.01610	.0936	.0000	154	Montrose and Ashland	
67	11- 6-12	5 30	22.33	N 19	47.0	93	29.19	2.71	67	Almost white	.291	.00225	.00768	.0000	.0936	67	School and Elston	Raining
56	9-27-12	7 00	24.42	SW-S 14	60 7	53	29.74	3.03	60	Very light	.061	.00154	.00921	.1005	.2064	56	Melrose and California	
57	10- 1-12	6 15	21.22	NE-E 7	60.0	65	29 65	2 88	63	Very light	024	.00148	.00598	.0000	.3518	57	School " "	
70	11-11-12	5 30	22.48	SW 25	69.2	59	29.12	2.98	70	Light gray	.610	.00348	.00810	.0000	.5905	70	Dickens " "	
6	6- 7-12	8 00	23.50	NE 10	61.0	53	29.70	2.73	3	Used in No. 8	. .	.00147	.00548	.0515	.0747	6	Irving Pk. Bl. and 54th Ave.	Two days
8	6-10-12	7 15	23 34	E 13	75 0	41	29.65	2 75	3	Light gray	.33,	.00151	.00663	.0000	.2427	8	" " " "	
65	11- 1-12	6 00	23.91	NW 8	38 0	59	29.39	2 98	66	Used in No. 66	. . . .	.00408	.00343	.0452	.2560	65	Belden and Racine	
66	11- 5-12	6 00	20.56	S 8	56.6	78	29.32	2 66	66	Dark gray	.405	.00810	.00731	.2042	.8107	66	Huber and Racine	
148	6-12-13	6 45	19.22	W 9	56 0	69	29.62	3 91	160	Black	.468	.01375	.01846	.1362	.4841	148	Fullerton and Racine	Night
83	1-16-13	6 05	21.64	S 17	47 0	95	29.23	3 62	87	Gray	.231	.02120	.00754	.1342	.8684	83	Churchill and Robey	
27	7-20-12	8 00	27.68	SE 8	64 0	75	29.58	2.74	22	Dark	.401	.00597	.00789	.0488	.4742	27	Vedder and Penn.	Night, rain
28	7-20-12	8 00	25.17	E 12	70.0	77	29.43	2.81	23	Rather light	.457	.00194	.01340	.0731	.0921	28	" " "	
9	6- 1-12	9 30	26.59	SW-N 14	75 0	46	29.48	2.57	4	Gray	.944	.00502	.00681	.0474	.3172	9	Emily and Paulina	
22	7-12-12	7 45	22.70	SE 7	71.0	75	29.39	3.14	17	Rather dark	.427	.01343	.05322	.1502	.5490	22	" " "	Night
10	6-13-12	7 30	17.71	NE 14	63 0	74	29.31	2.65	5	Light gray	1 085	.01090	.01532	.0000	.7428	10	Ohio and Peoria	
11	6-14-12	7 45	22 31	E 13	65.0	80	29 01	2.96	10	Dark	.645	.00645	.01235	.1370	.8492	11	" " "	
21	7-11-12	8 10	23.02	N 8	70 0	87	29 42	2 89	16	Very dark	886	.01008	.02873	.0633	.5966	21	" " "	Night
160	6-27-13	6 00	22.70	W 11	93.7	44	29.40	3.14	174	Very light gray	.639	.00288	.01818	.0760	.0204	160	Wood and Harrison	
62	10-29-12	6 30	23.37	SW 23	61.5	62	29.04	3 11	61	Gray	1.113	00851	.00564	.1750	.8413	62	Pearson and Lafayette	
29	7-25-12	7 00	23.05	NW 15	87.0	46	29.36	2.52	24	Light gray	1 150	.00227	.01107	.0960	.2460	29	Washington Bl. and Talman	
42A	8-19-12	6 10	22.77	SW 15	70.0	91	29.38	3 11	39	Very light	.119	.00161	.02634	.1620	.7380	42A	" " " "	Night, rain
159	6-26-13	6 15	21.18	SW 16	87.4	54	29.34	3.22	173	Very light gray	.472	.00617	01424	.1584	.0000	159	Groveland south of 31st	
78	12-10-12	6 05	15.56	SW-W 22	39.0	67	29 09	3.00	78	Light gray	1.414	.00761	.00606	.0000	.4315	78	44th and Ingleside	
35	8- 2-12	7 20	23 08	NE 13	72.6	62	29 52	2 61	26a	Very light	.277	.00334	.02899	.0000	.2095	35	McKinley Park North Side	
153	6-18-13	6 30	24.35	N-SW 7	62.6	76	29.54	3 69	167	Dark gray	.616	.01138	.01144	.0000	.3520	153	" " " "	Night
39	8-16-12	7 45	20 01	NE 11	63.0	70	29.64	2 68	35	Very light	.100	.00306	.01502	.0705	.2317	39	Princeton and 52d	Night
38	8-15-12	7 45	26 49	NE 16	68.0	73	29 63	2 80	33	Rather light	691	.00405	.00881	.0988	.5424	38	Lowe and 56th	
76	12- 6-12	7 05	25.19	W 23	28.0	84	29.51	2.79	76	Gray	1.587	.00359	.00416	.0963	.2032	76	Kimbark and 51st	Dirt
72	12- 2-12	6 25	24 98	NW 21	37.1	87	29 29	2.85	72	Gray	.620	.00842	.00463	.0730	.4992	72	Star Ave. and 65th	Street wet
79	12-11-12	6 25	24.54	NW-W 17	18.0	68	29 50	2 88	75	Light gray	1.324	.00310	.00221	.0649	.1871	79	Prairie and 67th	Dirt
149	6-13-13	6 20	18 23	W 10	71 0	66	29 46	3 96	162	Very black	850	.01134	02470	.3090	1 6170	149	42d Pl. and St Lawrence	Night

TABLE CXXIV. OBSERVED DATA AND RESULTS OF AIR ANALYSES
RAILROAD DISTRICTS

Test No.	Date	Duration of Test Hr. Min.	Volume Cubic Meters	Wind Dir. and Velocity Mi. per Hr.	Temperature Deg. F.	Relative Humidity Per Cent	Barometric Pressure Inches	Carbon Dioxid Parts in 10,000	Filter		Milligrams per Cubic Meter					Test No.	Test Location	Remarks
									No.	Color	Solids	Nitrous Acid	Ammonia	Chlorin	Sulphuric Acid			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	5-20-12	6 25	7.48	SW-N 17	69.0	69	29.31	3.25	x	Light	6.290	.01976	.01336	.6210		1	Clark and 12th	Rain
25	7-17-12	7 25	25.38	NE 8	62.5	76	29.56	2.77	20	Rather dark	.085	.00784	.00497	.0739	.5570	25	" " "	Night
132	5-13-13	5 50	17.00	NE-E 13	54.6	84	29.24	3.60	142	Very dark gray	.324	.01126	.01303	.2878	.0172	132	Taylor and Federal	Rain
141	6- 4-13	6 10	22.97	N 10	55.0	77	29.46	3.64	150	Light gray	1.198	.00721	.00094	.0602	.5267	141	Dearborn and Polk	Night
158	6-24-13	6 20	23.90	S 16	82.0	67	29.23	3.59	172	Gray	2.050	.01355	.01806	.0564	.5525	158	Plymouth Ct. and Polk	Street debris
133	5-14-13	6 00	21.91	NE 16	53.6	82	29.34	3.71	143	Gray	.365	.00822	.00592	.1650	.0252	133	Monroe and Canal	
29	7-25-12	7 00	23.05	NW 15	87.0	46	29.36	2.52	24	Light	1.150	.00227	.01107	.0960	.2460	29	Washington and Talman	
42A	8-19-12	6 10	22.77	SW 15	70.0	91	29.38	3.11	39	Very light	.119	.00461	.02634	.1620	.7380	42A	" " "	Night, rain
32	7-29-12	6 25	23.76	E 8	76.5	69	29.34	2.57	26	Rather gray	.147	.00318	.00683	.0000	.1839	32	LaSalle and 26th Pl.	
105	3-22-13	6 15	23.76	E 7	29.0	68	29.96	3.21	110	Light gray	.147	.01065	.00129	.0612	.5890	105	Shields and 34th	
14	6-20-12	11 45	25.96	SW-NE 13	70.5	61	29.42	2.74	7	Dark	.428	.00348	.01104	.0989	.2265	14	Dearborn and 36th	
75	12- 5-12	6 05	21.69	S 15	55.0	91	29.12	3.11	54	Rather dark	1.822	.01069	.01042	.1879	.6130	75	Armour and 37th	
74	12- 4-12	6 25	19.36	SW-SE 6	42.0	85	29.30	2.95	73	Dark	1.007	.01401	.00647	.1188	.5800	74	Shields and 44th	
39	8-10-12	7 45	20.01	NE 11	63.0	70	29.64	2.68	35	Very light	.100	.00306	.01502	.0705	.2317	39	Princeton and 52d	Night
80	12-13-12	6 35	21.55	SW 18	40.0	58	29.45	3.01	80	Dark gray	2.413	.00395	.00296	.2358	.7700	80	Shields and 53d	R.R. smoke
107	3-26-13	6 30	20.88	N 15	27.1	88	29.27	3.13	113	Dark gray	.335	.01848	.00321	.0874	.8168	107	" " "	Snow
38	8-15-12	7 45	26.49	NE 16	68.0	73	29.63	2.80	33	Rather light	.691	.00405	.00881	.0988	.5424	38	Lowe and 56th	
20	7- 9-12	8 10	20.57	SW-S 11	87.0	66	29.43	2.57	15	Very light	.486	.00556	.01060	.2106	.5260	20	Muskegon and 90th	Bessemer Pk
85	1-20-13	6 35	19.44	NW 19	24.1	90	29.33	4.23	88	Very black	2.016	.00756	.00359	.3665	2.0760	85	47th near Center	Cinders
47	8-24-12	7 15	24.42	SW 16	66.5	75	29.37	3.15	48		.143	.00430	.01380	.1403	.1551	47	Emerald and 41st	Night
45	8-23-12	7 35	22.45	W 9	59.5	84	29.25	3.32	40		.178	.00457	.00947	.2291	.1492	45	Union and 59th	Night
46	8-23-12	8 00	24.32	W-NW 11	69.0	62	29.36	3.20	41		.129	.00490	.01374	.2398	.3585	46	" " "	
63	10-30-12	5 45	16.21	E 7	46.0	67	29.50	2.97	65	Gray	.432	.00338	.00601	.0500	.4548	63	Clybourn and Southport	
116	4- 9-13	6 00	24.70	E 17	40.0	96	29.27	3.15	122	Light gray	.162	.00249	.00516	.0000	.0682	116	Michigan and Congress	Rain
131	5-12-13	6 10	25.22	SW 20	71.5	45	29.23	3.99	141	Dark gray	1.249	.01080	.00646	.2125	1.5940	131	Michigan and Randolph	
144	6- 7-13	7 25	25.15	N 28	47.0	79	29.48	3.11	155	Light gray	1.411	.00297	.00335	.0000	.7112	144	Monroe east of Michigan	Night
87	1-31-13	6 45	23.74	W 26	19.1	68	29.15	4.07	91	Black, cinders	6.791	.00510	.00069	.3920	.5474	87	" " " "	Dirt
118	4-11-13	6 20	22.97	SW 16	46.0	80	29.14	4.11	124	Dark gray	.849	.00753	.00425	.3538	1.5240	118	" " " "	Street wet
150	6-14-13	6 45	19.23	SW 9	70.0	54	29.37	4.06	163	Very black	.572	.01061	.00901	.2720	1.6710	150	Grant Pk. opp. Jackson	Night
159	6-26-13	6 15	21.18	SW 16	87.4	54	29.34	3.22	173	Very light gray	.472	.00617	.01424	.1584	.0000	159	Groveland south of 31st	
72	12- 2-12	6 25	24.98	NW 21	37.1	87	29.29	2.85	72	Gray	.620	.00812	.00463	.0730	.4992	72	65th St. and Star Ave.	
88	2- 1-13	6 35	20.02	W 16	9.0	78	29.68	3.51	92	Dark	1.808	.00871	.00211	.1105	.3576	88	47th and Robey	
51	8-28-12	6 35	23.93	S 18	63.0	71	29.37	3.31	50		.326	.00674	.00716	.0000	.2461	51	18th and Oakley	Night
48	8-26-12	7 45	26.69	SW 15	73.0	82	29.25	2.79	43		.019	.00428	.01989	.0000	.0953	48	14th and Western	Night
122	4-25-13	5 55	23.82	NW-N 7	46.0	91	29.45	3.19	134	Gray	.168	.00782	.00382	.0947	.9224	122	Canal south of Randolph	Rain
64	10-31-12	6 00	13.79	NE 7	43.7	95	29.24	3.78	64	Very black	1.414	.01138	.00376	1.3370	6.1480	64	Chicago and Halsted	Foggy, rain
130	5- 9-13	6 15	20.83	N 19	44.0	60	29.75	3.95	140	Very black	7.771	.00643	.00438	.7580	2.6110	130	" " "	Street debris
59	10-14-12	6 30	17.73	SW 19	63.5	43	29.52	3.34	50	Quite dark	1.297	.00696	.00662	.1896	.6127	59	Hawthorne west of Larrabee	
53	8-30-12	8 10	28.35	SE 15	66.0	83	29.47	3.49	42	Very dark	.829	.00511	.00614	.0467	.7237	53	Kinsie and Clinton	Night
54	8-30-12	7 00	18.29	S 11	77.6	72	29.40	3.31	53	Dark	1.121	.00970	.01275	.0682	1.8510	54	" " "	
109	3-28-13	6 15	24.81	S 27	41.0	68	29.47	3.39	115	Dark gray	1.710	.00916	.00479	.1181	1.8530	109	" " Canal	
81	12-16-12	6 20	15.73	E-SE 10	40.0	89	29.28	3.30	81	Gray	.381	.01228	.00260	.2825	1.0000	81	Austin and Ashland	
113	4- 5-13	6 00	23.14	W-NW 12	51.0	59	29.50	3.19	119	Rather gray	.938	.00396	.00351	.1446	.4501	113	Carroll and Wood	
121	4-24-13	5 45	20.40	S 25	72.0	62	29.26	3.28	132	Gray	2.304	.00891	.01142	.1517	.6234	121	Austin and Hoyne	
40	8-17-12	8 00	26.70	SE 13	68.0	75	29.55	3.08	37	Very dark	.554	.00825	.01130	.1204	.9640	40	" " Artesian	Night
41	8-17-12	7 45	20.80	S-SW 16	87.6	62	29.44	3.17	38	Dark	1.658	.00672	.01503	.0560	.8882	41	" " "	
71	11-13-12	6 00	22.63	NW-W 20	41.2	84	29.12	2.97	71	Gray	.221	.00421	.00383	.1480	.3845	71	California and Fulton	
69	11- 9-12	6 10	19.58	NW-W 6	47.0	63	29.58	3.02	69	Rather dark	1.047	.01066	.00994	.0544	.3742	69	Wade and Crittenden	
52	8-29-12	6 45	20.43	NE 11	65.0	87	29.41	3.43	57		.189	.00239	.01059	.0605	.0929	52	Sacramento and Chicago	Night
77	12- 9-12	6 30	18.51	SW 22	28.0	58	29.44	2.89	74	Gray	1.809	.00544	.00239	.1080	.4893	77	Princeton and 28th	
127	5- 6-13	5 45	17.18	NE 9	56.3	65	29.63	3.49	131	Very dark	.291	.00517	.00748	.1855	1.6070	127	55th and Normal	
145	6- 9-13	6 15	22.50	NE 13	51.0	60	29.83		158	Very black	.222	.00386	.00616	.3609	1.0252	145	" " "	Night
134	5-16-13	6 20	19.43	E 9	56.6	68	29.33	3.34	144	Gray	2.316	.00418	.00750	.1030	.0190	134	90th and Mackinaw	

152 Humboldt Park, Music Court, June 17, 1913, night.	166. Gray. Very little mineral matter, little animal and vegetable debris, insect parts, fiber, soot.	Open space between boathouse and pavilion covered with gravel. Boulevard W. with meadow beyond, lagoon N. of boathouse.
30–1 Garfield Park, July 26–27, 1912.	25. Brown. Fine mineral matter, organic debris, fibers, very small pollen, little soot, little coal.	On boulevard S. of bandstand, about center of park. Madison St. N. a short block.
155 Garfield Park, June 20, 1913, night.	169. Very light gray. Quantity of material collected small. Insect parts, vegetable debris, soot, very little mineral matter.	Oiled macadam drive S. of bandstand, one block south of Madison St., trees near, no traffic. S. W. wind off meadow.
115 Lincoln Park, Lake Front, April 8, 1913.	121. Trace of gray. Vegetable matter, few pieces of cinder, ash spheres, fiber.	E. side of granitoid road, cement sidewalk and stone beach between auto and lake. S.E. wind.
129 Lincoln Park, May 8, 1913.	129. Very light gray. Cinders, coal ash and ash spheres, very little organic debris.	High ground by Grant monument, lagoon below on W., on E. road, lagoon and lake, granitoid paving.
151 Lincoln Park, June 16, 1913, night.	164. Very dark gray. Fine mineral matter, cinders, soot, debris, vegetable fibers and debris, animal debris.	By Grant Monument, high ground overlooking lagoon on W. and drive with lake beyond on E. Trees and vegetation, oiled boulevard with no traffic passing.
112 Grant Park, Lake Front, April 2, 1913.	118. Very light gray. Some coarse cinders, animal debris and ash, number of ash spheres and few sharp edged irregular glass-like masses, suggesting bits of broken slag, like 144 from test, little organic debris.	S. E. wind.
150 Grant Park, opp. Jackson June 14, 1912, night.	163. Very black. Rather fine organic debris with considerable cinders, soot.	Grass N., grass and gravel S., oiled macadam pavement, no traffic, smoky.
87 Monroe, east of Michigan, Jan. 31, 1913.	91. Black. Pulverized dirt, fine cinders, mineral and organic debris, largely cinders, spheres of ash, soot.	Wind blew much fine material from ground N. of auto. Not much smoke from I. C. R. R. W. wind N. at location.
116 Michigan and Congress April, 1913.	122. Light gray. Coarse coal, cinders, soot, little mineral debris, little organic debris, fibers, few ash spheres only.	Ground wet from rain. E. side of asphalt street. I. C. R. R. depressed, with vacant grass plot between auto and R.R.

118 Monroe, east of Michigan, April 11, 1913.	124. Dark gray. Coal, charcoal, cinders, soot, many spheres, mineral debris, organic debris and fibers.	Smoke from I. C. R.R. blew S.E., street wet from rain till about 2 P. M.; many autos on asphalt street. I. C. R. R. 200 feet E. (See test 87.)
73 University of Chicago, Dec. 3, 1912.	55. Gray. Few cinders, coal, organic debris, ash, little soot.	Campus, gravel roadway, grass covered parkways and lots.
108 Washington Park, March 27, 1913.	114. Cinders, ash, mineral debris.	Ground covered with ice, which melted by end of test.
114 Jackson Park, Lake Front, April 7, 1912.	120. Almost white. Mineral matter, little cinders and soot, vegetable tissue and fiber, little organic debris.	Near "La Rabida." Location in eddy of wind which probably brought some land dirt into filter. Spray kept gravel walk wet. Wall between walk and lake, granitoid road.
131 Randolph, east of Michigan, May 12, 1913.	141. Dark gray. Mineral and organic debris, ash, cinders, soot, vegetable fibers and wood, pollen, ash spheres.	Boulevard S. lot, autos and teams on blvd. Blvd. construction one block S. I. C. R. R. terminal N. E.

RESIDENCE

120 Wilson and Ashland, April 18, 1913.	127. Slightly gray. Much coarse mineral debris, some ash, coal, little soot, vegetable fibers.	Ravenswood residence district. Asphalt street, school one block N., little traffic, N. W. wind off vacant lawn.
154 Ashland and Montrose, June 19, 1913, night.	168. Light gray. Very fine mineral matter, vegetable debris and hairs, pollen, starch, soot, wood.	Ravenswood residence district. S. S.W. wind. Asphalt street on Ashland, Montrose brick with car tracks, no cars till after 6 A.M. No trees, no traffic except milk wagons till after 6:30 A.M. and then light.
67 School and Elston, Nov. 6, 1912.	67. Almost white. Much organic debris, wheat and corn cells with starch, mineral matter, wood, paint films, very little soot, small amount of coal ash.	Made during a rain, barn near N., N. wind, few residences, unimproved street.
56 Melrose and California, Sept. 27, 1912.	60. Very light. Mostly coarse mineral matter, organic debris, very few starch granules.	Residence.
57 School and California, Oct. 1, 1912.	63. Very light. Residue largely mineral matter, much vegetable and animal tissue, a bit of feather fibers, numerous pollen grains, starch, not much soot or coal dust.	Chickens in lot near location. Unimproved street, few residences, N.E. wind. Commonwealth Edison Co. station one block N. E.

70 Dickens and California, Nov. 11, 1912.	70. Light gray. Little coarse mineral debris, little organic debris, very little ash and soot.	Residence district, vacant lots N. and S. Street cars 250 feet E. Blvd. three blocks W., no factory or R. R. near.
148 Racine, between Huber and Fullerton, June 12, 1913, night.	160. Black. Animal and vegetable debris, fine mineral matter, pollen, much soot.	Shady street, many trees, Alexian Brothers Hospital S. W. Asphalt street with one car track, no cars between 1:00 A.M. and 6 A.M. Factory N.W. Deering works W. where it was very smoky in early morning but cleared later.
83 Churchill and Robey, Jan. 13, 1913.	87. Gray. Few large pieces of mineral or ash, little organic debris, cinders and soot.	Lumber yard E., R. R. S. one block, street cars E., ground wet, misty day.
160 Wood, between Harrison and York, June 27, 1913.	174. Very light gray. Much mineral debris, few cinders, fibers, little organic debris, few pollen.	Cook County Hospital on W. side of street, brick paving, dirty, not sprinkled all day, heavy auto (brewery) traffic making much dust.
62 Pearson, between LaFayette and Lincoln, Oct. 29, 1912.	61. Gray. Fine mineral matter, much coal and soot, organic debris, very few small pollen mold, starch.	Residence district with smoke from Chicago Ave. Pumping Station, rained before test, asphalt street.
29 Washington Blvd. and Talman, July 25, 1912.	24. Light. Much gritty mineral matter, some organic matter of indefinite structure, organic debris and fibers, few pollen, coal, soot.	Residence district, railroad passing W. N. W. wind, granitoid paving.
42-A Washington Blvd. and Talman, Aug. 19, 1912, night.	39. Very light. Some mineral matter, some large pieces of indefinite organic structure, many small pieces, coal or cinders, soot.	Same as test No. 29, raining, S. W. wind.
159 Groveland, south of 31st, June 26, 1913.	173. Very light gray. Considerable coarse mineral matter and ash, cinders, coal, soot, animal and vegetable debris, starch.	Clean brick paving, hospital and breweries N. one block, I. C. R. R. E. one block, little traffic, S. W. wind.
35 McKinley Park, Aug. 2, 1912.	26-A. Very light. Fine mineral matter, organic debris, plant hairs, animal hairs, coal or cinders, very little soot, corn starch.	Location of test on cinder drive N. side of park, N.E. wind, residences about park.
153 McKinley Park, June 15, 1913, night.	167. Dark gray. Fine mineral debris, ash, cinders, coal, soot, much vegetable debris, starch, animal matter, fibers, few pollen.	Shrubbery, cinder drive with lagoon S. across grass plot, houses N. beyond tall hedge. No factories, R.R. about one mile S.W.

39 52d and Princeton, August 16, 1912, night.	35. Very light. Organic debris, mineral matter, spores of fungus, several varieties of pollen, animal hairs, coal, soot and starch.	R. R. W. — N.E. wind, residence.
38 Lowe and 56th, Aug. 15, 1912.	3. Rather dark. Mineral matter, bits of some crystalline structure, organic debris, few pollen, coal, little soot.	R. R. yards N.E. with N.E. wind, otherwise residence district, unimproved street.
76 51st and Kimbark, Dec. 6, 1913.	76. Gray. Vegetable fibers and tissue, woody fiber, some mineral debris, little ash, soot.	Rather open residence district, vacant lot N. bordered by wood fence, some trees, no smoking chimneys observed.
72 65th and Star Dec. 2, 1912.	72. Gray. Cinders, coal, soot, numerous ash spheres, ash, mineral matter, little organic debris.	Residence except for I. C. R. R. one block W., frequent trains, rained night before, N.W. wind.
79 67th and Prairie, Dec. 11, 1912.	75. Light gray. Considerable mineral debris, ash, charcoal, little cinders and soot, vegetable matter, wood fiber.	Macadam street from which wind blew much dirt, autos passing frequently raised dust, R. R. one block E.
149 42d Place and St. Lawrence, June 13, 1913, night.	162. Very black. Fine mineral debris, cinders, soot, animal and vegetable debris, fibers, occasional pollen.	Residence district, no factory or R. R. near. Oiled macadam street, brick alley, dirty, much smoke early in morning in W., some milk wagon traffic.

MIXED RESIDENCE

33 29th, West of Halsted, July 30, 1912.	29. Light. Mineral matter, many colored fibers, wool, hair, much corn starch, few minute pollen, considerable mold spores, sawdust and woody fiber, coal and soot.	Playground S., vacant lot N., residences, S.
42-B 29th, West of Halsted, Aug. 20, 1912.	36. Dark. Mineral matter, very much starch, mostly corn starch, few pollen, fibers, hair, coal and soot.	Playground S., vacant lot N., residences.

(All other filters belonging to this class are described in connection with other classes of location.)

INDUSTRIAL

113 Carroll and Wood, April 5, 1913.	119. Rather gray. Coarse mineral debris, cinders, coal, charcoal, ash, soot, few black spheres, animal hair, organic debris, vegetable matter.	Some smoke from locomotives on tracks one block N., no factory smoke, pickle factory W. one block, asphalt paving, ground damp.

60–61 Commonwealth Edison Co., N.W. Plant, Oct. 25–26, 1912.	56. Very light gray. Fine mineral matter, animal hair, little starch, organic debris, coal, apparently charcoal, soot.	Inside of plant, location No. 60 S.W. of building with N. wind blowing across entrance to coal and ash pits. No. 61 N.E. of building with S.W. and W. wind. Small bonfire west for a few minutes.
63 Clybourn Place and Southport, Oct. 30, 1912.	65. Gray. Fine mineral matter, charcoal or charred wood, coal, soot, organic debris.	Vacant lot on river, R. R. S., factories and foundry near. Moulding factory E. with E. wind.
68 Division, between Hickory and Hooker, Nov. 8, 1912.	68. Dark gray. Organic debris, animal hair, coal and charcoal in appreciable quantities, soot, little starch, coarse and fine mineral matter.	High wind W., hay team tracks, street sweepers at work, cars, cobblestone paving, considerable teaming.
59 Hawthorne, between Hayes and Larrabee, Oct. 14, 1912.	59. Quite dark. Coarse and fine mineral matter, organic debris, animal hair, coal, charcoal, soot, little starch, few pollen, wood, fiber, bits of leaves.	Industrial district back of Montgomery Ward's, R. R. roundhouse across the river S. W. S. W. wind, unimproved street, switching at times, no trees near, much teaming on Chicago Ave. S.
101 Ohio and Morgan, March 17, 1913.	105. Gray. Some vegetable fiber, little hair, little organic debris or mineral debris, some cinders and soot.	Asphalt paving, some snow on ground, small air sample, battery discharged.
121 Austin, between Leavitt and Hoyne, April 24, 1913.	132. Gray. Much coarse mineral debris, ash and cinders, little soot, coal, charcoal, organic debris, vegetable fibers, molds, much woody tissue, animal hairs.	Brick paving, dirty, several lumber yards, some residences, R. R. one block S., S. wind.
71 California, N. of Fulton, Nov. 13, 1912.	71. Gray. Rather coarse cinders, coal, few spheres, little soot, little organic debris.	S. of C. & N. W. Ry., W. of coal yards; Griffin Wheel Co. W. one block, school S. one block.
37 Washington Blvd., off Halsted, Aug. 6, 1912.	30. Brown. Mineral matter, organic debris, hairs, fibers, soot.	Manufacturing district, S. wind.
119 Harrison and Desplaines, April 15, 1913.	126. Very dirty black. Much mineral debris and ash, organic debris, charcoal, vegetable fiber, including woody structure.	Foundry N.E. one block, blacksmith shop E. beyond vacant lot covered with brick, cobblestone paving, teaming, no residences.
146 Desplaines and Congress, June 10, 1912, night.	157. Dark gray. Coal, cinders, soot, mineral matter, ash, organic debris and fibers, plant hair, pollen.	Cobblestone paving, little traffic till 6 A.M., cars after 6:30 A.M., candy factory W. U. S. Exp. barns N. W., street damp.

49 16th, between Washtenaw and Rockwell, Aug. 27, 1912, night.	58. Numerous pollen in bunches, little mineral matter, debris and soot, mold spores.	
50 16th, between Washtenaw and Rockwell, Aug. 27, 1912.	51. Organic debris, mineral matter, numerous pollen, starch, hair fibers, little soot.	N.E. wind, residence district, Douglas Park W., Ryerson warehouse E., B. & O. and C. B. & Q. E.
36 Poplar, off Archer, Aug. 5, 1912.	31. Very light. Mineral matter, organic debris, starch, no pollen, little soot, coal.	Residence district, N.E., E. wind.
34 Loomis, off 22d St., Aug. 1, 1912.	28. Much woody tissue, organic debris, sand, few pollen and spores, hair, fibers and starch.	Lumber yards, S.W. wind blowing across river, plank paving.
126 Emerald and 39th, May 5, 1913.	130. Dark gray. Much cinders, soot, ash, spheres of ashes, not much organic debris.	Emerald Ave., asphalt paving, 39th St. granite block in tracks, vacant lot W., houses E., brewery S., Pfaelzer Sons' Co. S., ground wet, R.R. one block S.
47 41st and Emerald, Aug. 24, 1912.	48. Mostly mineral matter, much vegetable and animal tissue, sawdust, colored fibers, starch, numerous pollen, much coal, soot and ash.	Stockyards S. W. with S. W. wind.
86 43d and Halsted, Jan. 22, 1913.	84. Quite black. Organic and mineral debris, vegetable and animal fibers, cinders, soot and coal.	Snow on ground, street cars W. one block, residence E., E. of stockyards, S. wind, saloons on corners.
43 Emerald and 46th, Aug. 31, 1912.	32. Very dark. Mineral matter, much organic debris, indefinite masses, mold spores, few pollen, fibers, much cinders or coal, soot.	Wind off stockyards.
45 Union and 50th, Aug. 23, 1912.	40. Much mineral matter, sawdust, much starch, possibly wheat, numerous pollen, much soot, coal and ash.	W. of Pennsylvania yards, with W. wind.
85 47th, near Center, Jan. 20, 1913.	88. Very black. Large coarse cinders, coal, charcoal, ash, few spheres, soot, organic debris, vegetable fibers, pollen grain or two.	S. of stockyards, N.W. wind, just S. of Belt Ry. tracks, snowing at times, ground covered with snow.
44 Marshfield and 45th, Aug. 22, 1912, night.	34. Dark. Numerous pollen in bunches, several varieties, much corn starch, mineral matter, organic matter, soot, mold spores.	W. and S. W. wind, W. of stockyards near play grounds.

128 42d, E. of Ashland, May 7, 1913.	135. Dirty gray. Animal debris, little ash, coal, cinders, charcoal, organic debris.	E. of stockyards, fertilizer plants near, street cars W. 100 feet, granite blocks.
134 90th and Mackinaw, South Chicago, May 16, 1913.	144. Gray. Many angular bits of clear particles, like bits of broken glass or slag, containing gas bubbles not observed in other specimens, cinders, soot, many minute spheres most of them clear, pollen, organic debris, much small mineral matter, debris and ash, fibers, one long filament of glass-like material with elongated air or gas bubbles.	Residences, unimproved street, no traffic, no dust, blast and Bessemer converter furnaces N. one mile, rolling mills N. W., slip and ore piles E., smoke not blowing directly toward auto.
157 Congress, east of Center, June23,1913.	171 or 177. Light gray. Little cinders and soot, mineral and organic debris, bits of bluish film.	Brick paving, teaming, pie factory E., garter factory S.W., blacksmith shop N.E.
147 Congress, east of Center, June 11, 1913, night.	159. Very black. Fine mineral debris, cinders, soot, organic debris.	Brick paving, bakery one block E., no cars, little traffic till after 6:30 A.M.

RAILROADS

132 Taylor, corner Federal, May 13, 1913.	142. Very dark gray. Cinders, charcoal, ash, animal and organic debris, fibers, few pollen and very minute ash spheres, soot.	Dearborn Station N.E., rough cobblestone paving, much teaming, freight house N., hard rain.
141	See Loop Class.	
158	" " "	
133	" " "	
29	" Residence "	
42–A	" " "	
32 La Salle and 26th, July 29, 1912.	26. Rather light. Mineral matter, organic debris, hair, occasional pollen and starch.	Railroads E. with E. wind, street unimproved, residences.
105 Shields and 34th, March 22, 1913.	110. Light gray. Organic debris, ash, cinders, soot, mineral matter, ash spheres and charcoal.	Vacant lot W., one block to R. R., asphalt street; snow over part of ground, no buildings, no cars, little traffic, ball park S. E.
75 37th and Armour, Dec. 5, 1912.	54. Rather dark. Cinders, coal, soot, organic debris and ash.	Rained the previous night, R.R. one block W., "L" one block E., stores, laundry, bakery on street.
74 44th and Shields, Dec. 4, 1912.	73. Dark. Vegetable debris, ash, cinders, coal, charcoal, soot, not much mineral debris.	R. R. one block W., playground S. one block.
39	See Residence Class.	
80 53d and Shields, Dec. 13, 1913.	80. Dark gray. Cinders, ash, soot, few spheres, coal, charcoal, vegetable matter, fibers, wool fibers, mineral debris.	P. F. W. & C. Ry., W., S. end of yards with roundhouse S.W., grass along R. R. burned in afternoon, trains frequent, S.W. wind.
107 53d and Shields, March 26, 1913.	113. Dark gray. Mineral debris, ash, cinders, little soot, organic debris and few ash spheres.	Brick paving on 53d, no paving on Shields, vacant lot N., R. R., W., houses and stores, ground frozen, snow.
38	See Residence Class.	
85	" Industrial "	
47	" " "	
45	" " "	
46	" " "	
63	" " "	
116	" Park "	
131	" " "	
144	" Loop "	
87	" Park "	
118	" " "	
150	" " "	
159	" Residence "	
72	" " "	
88 17th and Oakley, Feb. 1, 1913.	92. Dark. Much vegetable debris and fiber, animal hairs, woody fiber, mineral debris, ash, cinders, soot and corn starch.	C.B. & Q. yards N. and W., asphalt at cars ½ block S., vacant lots covered with ice.
122	See Loop Class.	
130 Chicago and Halsted, Viaduct, May 9, 1913.	140. Very black. Quantities of street debris, much coarse mineral debris and ash, cinders, little soot, much vegetable debris and fiber including wood, charcoal, ash spheres, animal hair, a pollen grain or two.	R. R. roundhouse N. E. but smoke from it did not blow directly toward the auto, river one block W. wood paving slightly damp, sprinkled in car tracks once, much teaming.
59	See Industrial Class.	
53 Kinzie and Clinton, Aug. 30, 1912, night.	42. Very dark. Much gritty mineral matter, coal or cinders, soot, organic debris, woody fiber, occasional starch and pollen, fibers, indefinite organic masses.	R. R. yards, obblestone paving, S.E. wind off yards, teaming.
54 Kinzie and Clinton, August 20, 1912.	53. Much coarse mineral matter, animal and vegetable debris, wood, some starch, numerous pollen, considerable soot, coal and ash.	Cobblestone street, railroad yards.
109 Kinzie and Canal, March 28, 1913.	115. Dark gray. Cinders, ash, mineral debris, soot, organic debris.	R. R. on elevated track W., track S. ¼ block, freight house across street, cobblestone paving wet.

81 Austin and Ashland, Dec. 16, 1912.	81. Gray. Vegetable and animal debris, ash, cinders, coal, soot, mineral debris, animal hair, spheres of ash, charcoal.	R.R. one block S., S.E. wind, factories and residences, street cars E. ½ block, paved street.
113	See Industrial Class.	
121	" " "	
41 Austin and Artesian, August, 17, 1912.	38. Dark. Mineral fragments, organic debris, soot, animal and vegetable fibers, pollen, mold spores, starch, coal.	S.-S.W. wind off C. & N. W. Ry., cattle trains passing.
40 Austin and Artesian, Aug.17,1912, night.	Same as No. 41.	
71	See Industrial Class.	
69 Wade and Crittenden, Nov. 9, 1912.	69. Quite dark. Cinders, ash, soot, mineral debris, little organic debris.	R.R. one block E., houses all around, livery stable across street, excavating lot N.
52 Sacramento and Chicago, Aug. 29, 1912, night.	57. Organic debris, much wood fiber, numerous pollen, considerable soot, coal and ash.	N. E. wind, R. R. roundhouse E.
77 28th, between Shields and Princeton, Dec. 9, 1912.	74. Gray. Considerable coarse mineral matter and ash, cinders, coal, charcoal, organic debris and fiber, woody tissue.	R.R. one block W., S.-S. W. wind, residence district, shop S. W.
127 55th Blvd., between Shields and Normal, May 6, 1913.	131. Very dark gray. Mineral debris, cinders, ash, many ash spheres, soot, organic debris, coal.	Rained night previous, opposite roundhouse with grass and oiled macadam road between auto and roundhouse, R.R. one block E., and another one block W., autos passing on boulevard.
145 55th and Normal, June 9, 1913, night.	158. Very black. Cinders, soot, mineral debris, organic debris, vegetable tissue.	Penn. roundhouse and yards N.E., residence district, asphalt blvd. with oiled macadam on side drive, grass strip between blvd. and drive, R.R. crosses street E. and W., no factories.
	LOOP	
131	See Park Class.	
87	" " "	
118	" " "	
144 Monroe, east of Michigan, June 7, 1913, night.	155. Light gray. Considerable coarse mineral debris, little ash, soot, cinders, vegetable debris, woody fiber, charcoal.	Granitoid paving blvd. W., I. C. R. R. 150 feet E., new grass N. for one block then dirt, N. wind.
116	See Park Class.	

95 Dearborn, south of Lake, Feb. 14, 1913.	99. Gray. Animal and vegetable debris, colored hairs and fibers, wood fiber, straw, grain, particles of charcoal, soot.	Cobblestone paving with wood blocks in car tracks, "L" north 100 feet, snow flurry, W. wind.
103 Dearborn, south of Lake, March 19, 1913.	107. Dirty white. Much vegetable fiber, little soot, hair, debris, ash spheres.	Cobblestone paving with wood block in car tracks, "L" on Lake St.
90 Randolph, between State and Dearborn, Feb. 6, 1913.	94. Dark and dirty. Much vegetable debris and fibers, woody tissue, colored fibers, animal debris and hairs, mineral debris, ash, cinders and soot.	Seed store adjacent, cobblestone paving, street cars, street cleaners.
94 Washington, west of Dearborn, Feb. 13, 1913.	98. Black paper, gray cotton. Very much coarse mineral debris, ash, cinders, soot, much coarse vegetable debris, woody fiber, hair.	Cobblestone paving, street cars, much street debris circulating, wind high and eddied, 22 miles per hour, S. W.
117 Washington, west of Dearborn, April 10, 1913.	123. Dark gray. Mineral matter and ash, cinders, coal, organic debris, vegetable fibers, animal hairs, ash spheres.	Cobblestone paving wet from rain of night, street cars.
140 Dearborn, north of Madison, June 3, 1913, night.	152. Dark gray. Cinders, some soot, mineral debris and ash, organic debris, wood, few small ash spheres, a pollen or two.	Wood blocks in tracks, cobblestone outside, little traffic, street swept by two men at 2 A.M., cars about every hour.
99 Dearborn, north of Adams, Feb. 21,1913.	103. Almost white, few specks. Cinders, soot, ash, few spheres of ash, rather coarse.	Wood block paving, wet, raining, street cars.
139 Dearborn, north of Adams, June 2, 1913, night.	151. Dark gray. Cinders and coal, some soot, very little ash and animal matter, few minute spheres.	Wood block paving, little traffic including cars till 6:30 A.M., no street sweepers.
102 Dearborn, between Adams and Monroe, March 18, 1913.	106. Dirty gray. Much vegetable debris, fibers, woody tissue, colored fibers, animal debris and hairs, coarse mineral debris, ash, cinders and soot.	Front of Marquette Bldg., wood block paving, street cars, street sprinkled at 1 P.M.
141 Dearborn and Polk, June 4, 1913, night.	150. Light gray. Very much fine mineral debris, ash, cinders, soot, vegetable and animal debris.	Dirty rough cobblestone paving, one man sweeping street at beginning of test and three hours later, 4 A.M., express, mail and baggage wagons, station opposite S.
158 Polk and Plymouth, June 24, 1913.	172. Gray. Very much coarse mineral debris, ash, soot, vegetable fiber, pollen, seed, animal and vegetable debris.	Cobblestone paving. Dearborn Station S., pile-driver placed in excavation N. during day, large printing plant E.

89 Clark, south of Adams, Feb. 5, 1913.	83. Dark rather than black. Cinders, soot, ash, mineral debris, vegetable debris, animal hairs, charcoal and spheres of ash.	Near postoffice, wood block paving, street cars, street cleaners.
104 Clark, south of Adams, March 20, 1913.	109. Dirty gray. Animal and vegetable debris, animal hair, wood fibers, vegetable debris, much animal debris, ash, coal, charcoal.	Wood block paving, street cars, street flushed at noon, crowd at noon.
138 Clark, south of Adams, May 30, 1913.	149. Gray. Cinders, coal, very little ash, organic debris, pollen.	Wood block paving. with cobblestone in tracks, little traffic.
156 Clark, south of Adams, June 21, 1913, night.	170. Very light gray. Few cinders, few particles of mineral and vegetable matter and little soot.	Rained during test, wood block paving with cobblestone in street car tracks, little traffic, cars at intervals.
96 Clark, south of VanBuren, Feb. 16, 1913.	100. Gray. Vegetable and animal debris, cinders, soot, some mineral debris, little ash and occasional ash spheres.	Cobblestone paving, street cars, no street sweepers, low buildings, Sunday test.
97 Clark, south of VanBuren, Feb. 17, 1913.	101. Gray. Mineral debris, much cinder and soot, vegetable matter, wood, hair, few pollen, and animal debris.	Cobblestone paving, street cars, low buildings, saloons, street sweepers, traffic.
100 Lake, near 5th Ave., March 10, 1913.	104. Very light gray. Little mineral matter, small vegetable debris, soot, few pollen.	Cobblestone paving, "L" above, surface cars, street wet.
106 Lake, west of La Salle, March 24, 1913.	11. Very light. Debris of all kinds, a few fibers, hair, soot.	Cobblestone paving, "L" and surface cars, street wet with rain.
143 Lake, between La Salle and 5th, June 6, 1913, night.	154. Gray. Much cinder, ash, many spheres, organic debris, woody tissue, animal debris, vegetable and animal fibers.	Cobblestone paving, street sweepers working at beginning of test, "L" above, surface cars stopped between 1 and 6 A.M., traffic began after 6 A.M.
91 La Salle, between Adams and Monroe, Feb. 8, 1913.	95 Considerable woody fiber, soot, ash, cinders, coal, insect parts, animal and vegetable debris, mineral debris.	Wood block paving, no cars in block, many people passing.
92 La Salle, between Adams and Monroe, Feb. 9, 1913, Sunday.	96. Dark gray. Not much surface dirt, vegetable and animal debris, woody fibers, charcoal, mineral debris, soot, cinders, pollen.	Wood block paving. no cars in block, street cleaners till noon, considerable traffic.
93 La Salle, between Adams and Monroe, Feb. 10, 1913.	97. Very dark gray. Much vegetable debris, woody matter, colored fibers, animal hairs, mineral debris, soot, cinders.	Wood block paving, no cars in block.
142 La Salle, between Adams and Monroe, June 5, 1913, night.	153. Very dark gray. Much fine mineral debris, ash, soot, organic debris, parts of insects, fibers and ash spheres.	Wood block paving, autos, mail and express wagons passing, cars on Monroe.
133 Monroe and Canal, May 14, 1913.	143. Gray. Cinders, ash, soot, coal, fibers, organic debris.	W. side of Union Depot, high wall W. side of street, cobblestone paving, wet from rain of previous night.
122 Canal, south of Randolph, April 26, 1913.	134. Gray. Cinders, coal, ash, organic debris, ash spheres, charcoal.	Cobblestone paving, soaked by rain, no street cars, Northwestern Depot W. side of street, cars on Randolph.
98 Market, near Monroe, Feb. 20, 1913.	102. Gray. Some dirt, much animal and vegetable debris, animal hairs, skin, colored wool and vegetable fiber, mineral debris, ash, cinders and soot.	No street cars, cobblestone paving damp, heavy teaming.

Owing to the difficulty of readily interpreting large groups of figures, the results of the air analyses have been arranged and plotted to form curves which convey at a glance the significance of the values determined. In calculating averages by classes of location preparatory to plotting the curves, a few results which varied widely from the averages have been omitted. For instance, in the park class, tests Nos. 150, 87, 116, 118 and 131 have been omitted because they were made in a location (Grant Park) which, while technically belonging to the park class, is in close proximity to a railroad line and also to the loop district, and the atmosphere at this point was regarded as being influenced by the presence of these polluting factors. The conditions were, therefore, not comparable with those obtaining in other parks. In the railroad class, several tests have been omitted. Test No. 1 was omitted because the rate of filtering as a result of motor trouble was much slower than that for any other test. Test No. 87 was omitted because of the presence in the air of a very large amount of surface dirt due to a high wind. The chlorin determinations in test No. 64 were omitted because the results were nearly twice as great as those of any other test, a condition which was probably due to the fact that the test was conducted on a foggy day. Sulphuric acid results from test No. 64 were also omitted for the same reason. In the mixed residence class, the chlorin determinations from night test No. 145 were omitted because of the exceptionally high values obtained. In the industrial class, determinations for solids were omitted from two tests because of accidents to the filters.

The results of the various determinations and the deductions to be made therefrom are presented in the sections which follow.

113.16 Solid Constituents of the Atmosphere as Determined by Air Analyses: The solid materials present in the samples of air which were collected in the total of 160 air analyses made in different parts of the city and the surrounding territory, were intercepted in the manner described (section 113.14) by means of specially prepared filters arranged in place in the intake of the apparatus. The solids thus entrained were then weighed and examined.

The average values for the solid materials for both the day and the night tests made in the various districts are presented as table CXXV.

TABLE CXXV. AVERAGE AMOUNTS OF SOLID MATERIALS FOUND IN AIR SAMPLES COLLECTED IN VARIOUS DISTRICTS

Milligrams per Cubic Meter					
Districts	No. Tests	Solids	Districts	No. Tests	Solids
Country	6 Day	0.049	Mixed Residence	20 Day	0.976
				5 Night	0.207
Park	20 Day	0.321		All	0.818
	4 Night	0.364			
	All	0.330			
Playground	6 Day	0.350	Boulevard	9 Day	0.707
	3 Night	0.261		5 Night	0.538
	All	0.327		All	0.697
Residence	24 Day	0.689	Railroad	36 Day	0.966
	9 Night	0.445		14 Night	0.488
	All	0.618		All	0.821
Industrial	24 Day	1.000	Loop	26 Day	1.958
	9 Night	0.361		7 Night	0.690
	All	0.826		All	1.689

A study of the values presented in table CXXV indicates that, as a rule, the amount of solids contained in samples collected during the day is greater than that contained in samples collected during the night. An exception to this general rule occurs in the case of samples collected in parks. The decrease noted during the night in industrial and residential districts is probably due to the fact that most of the industries are closed at night and also that there is less traffic on industrial and residential streets during the night than during the day. The difference between the amount of solids present in the samples collected during the day and in those collected during the night is not as marked in the case of boulevards as in the case of most of the other districts, a fact which may probably be due to a comparatively greater degree of activity on the boulevards during the night than is evident on most other thoroughfares. Particular attention is directed to the difference between the amount of solids present in the air during the day in the loop district and the amount present during the night, the value for the day being nearly three times as great as that for the night. This condition may be explained by the comparative cessation of activity in the loop district during the night, and also by the fact that the wind velocity during the night is usually lower than during the day. In order to disclose further the relation between the amount of solids present in the air during the day and the amount present during the night, the values have been plotted by rearranging the tests in the order of descending values for the solid materials found in samples collected during the night. A diagram showing this relation is presented as fig. 81.

It is evident that most of the day values are higher than the corresponding values for night tests. Especially is this true in the case of samples collected in the railroad and loop districts. It may also be noted that the values for solid materials contained in the samples collected during the night are generally higher for the railroad and loop districts than for other districts. There are nine instances in which the night values exceed the corresponding day values. In two of these instances the values are only slightly higher for night than for day. Three were park tests, one was made on the lake front, two were in industrial locations and one was an exceptional loop or railroad location where there was considerable vacant ground, namely, Grant Park west of the Illinois Central Railroad.

The exceptionally high values for solids obtained from tests in the loop district were probably due to such local conditions as heavy traffic and intense business activity. Two tests made at the same point, under wet and dry conditions respectively, yielded results which indicated the presence of considerably less dust in the atmosphere during periods of rain than during periods of dry weather. In addition to the data from which the determinations of the quantity of solids contained in air samples were made, much information was secured from a careful study and microscopical examination of the filters and their contents. Photographs of all filters were made. These photographs serve as permanent records from which comparisons may be made as desired. In photographing a series of filters, one unused or blank filter was placed in position with a number of filters through which air samples had been drawn. One of the photographs of a series of filters, in which the blank filter is shown in the upper left-hand corner, is reproduced as fig. 82.*

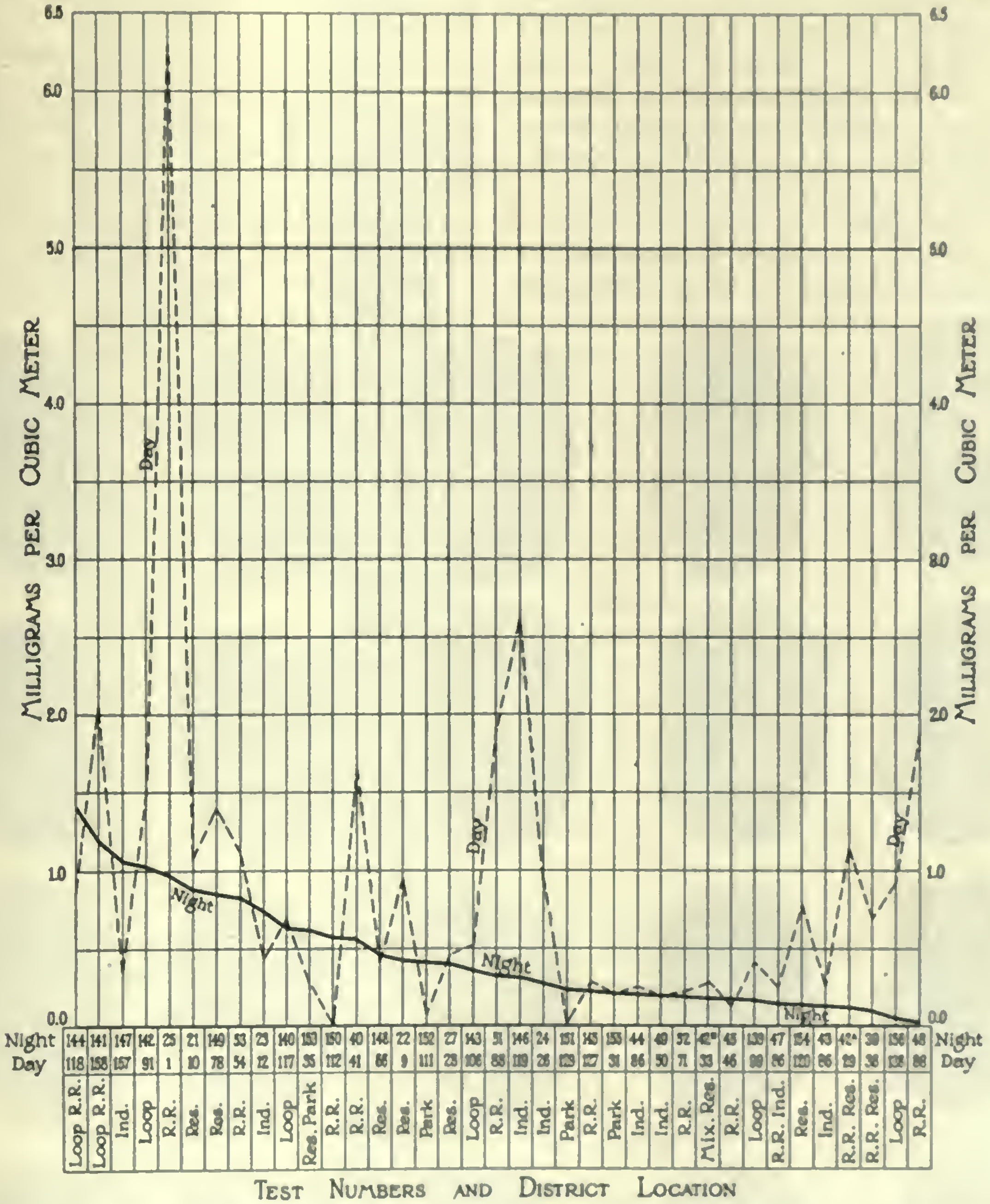


FIG. 81. COMPARISON BETWEEN THE SOLID MATERIALS PRESENT IN SAMPLES OF AIR COLLECTED DURING THE DAY AND THOSE COLLECTED DURING THE NIGHT

The color of the filter has been used by many investigators as a means of estimating the amount of carbonaceous material in the air. While observations of color may serve in a general

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* Additional photographs of filters used in tests are preserved in the Archives of the Committee, Vol. A 2.

way to aid in classifying the materials intercepted, it is evident that under certain conditions some of the solid constituents may be of a light color which neutralizes the dark color of the carbonaceous material, thereby giving an incorrect idea of the contents of the filter in question. The weight of the material and its chemical composition constitute, therefore, the only reliable guides to an understanding of its character. However, to illustrate the coloring or blackening property of carbonaceous material and of clay or sand, 5 grams of powdered paving block were placed in a glass tube, and 5 grams of finely divided soot were placed in a second tube of identical shape and capacity. From fig. 83 it is clear that the coloring powers of a given weight of soot are far greater than those of the same weight of powdered paving block.

As the work progressed, it was observed that the filters used in tests made during the night generally presented a darker appearance than those used in tests made under the same conditions at the same point during the day. As has been stated, however, the quantity of solids contained in the samples collected during the day was generally greater than that contained in the

FIG. 82. FILTERS AS APPEARING AFTER TYPICAL TESTS

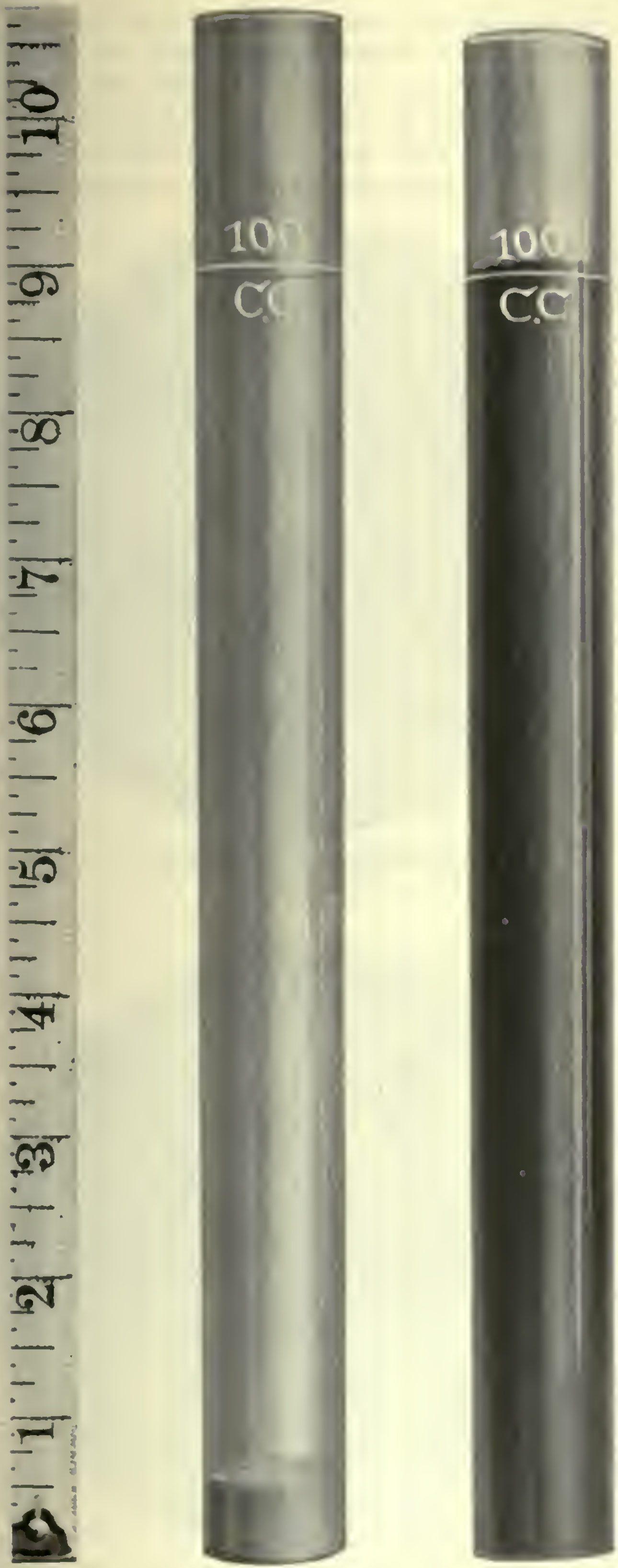


FIG. 83. COLORING POWER OF SOOT. Relative Volumes of Equal Weights of Dry Paving Block and Soot. Both Finely Powdered.

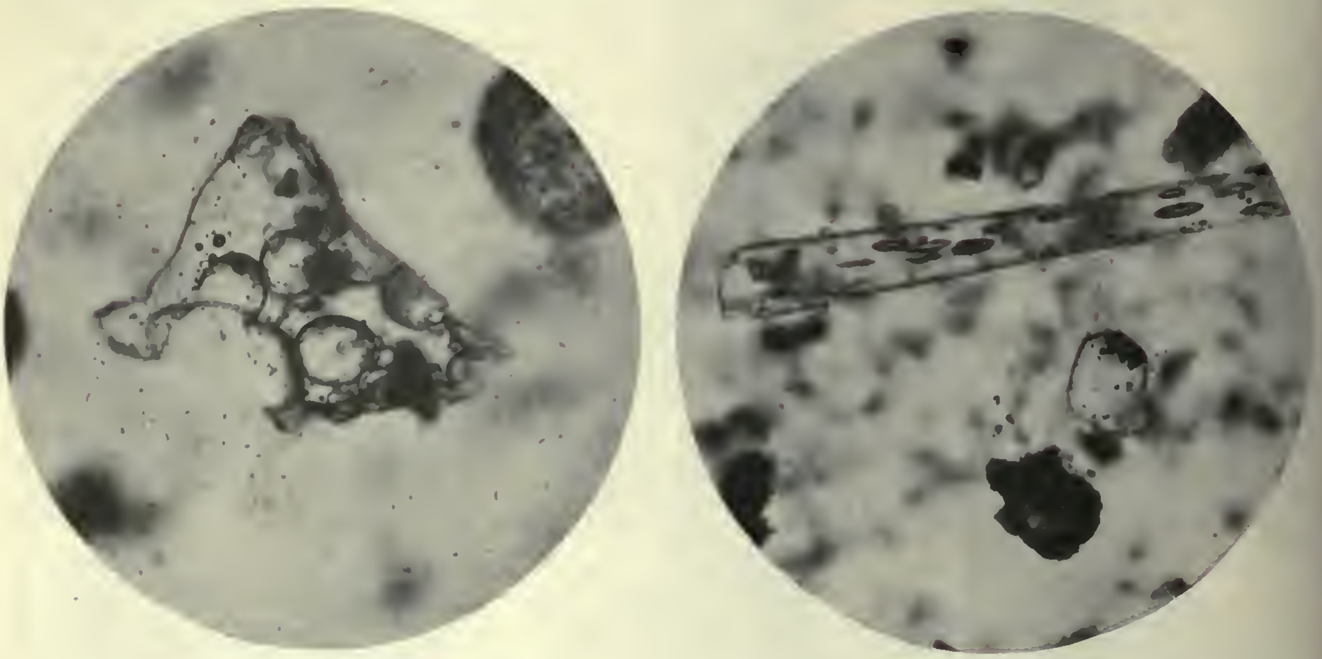
samples collected under similar conditions during the night. The dark color of the night filters can, therefore, be accounted for only upon the assumption that, during the night, the air contained less mineral debris and, consequently, a relatively higher amount of carbonaceous or sooty material, than during the day. The presence of a large proportion of such substances as sand and mineral debris in the solids collected during the day undoubtedly tended to neutralize the color of the carbonaceous material and thereby to cause the day filters to present a lighter appearance than the night filters. Microscopical examinations confirmed these facts.

Microscopical examination of the contents of filters was not undertaken until the investigation had proceeded for some time, and the first 28 samples collected were not, therefore, used in these determinations. Most of the samples examined were shown to possess general characteristics discernible only by means of the microscope. For instance, mineral, animal or vegetable debris of unidentified structure was noted in many of the samples, and generally the presence of minute spheres of fused ash was detected. The presence of ash in this form was regarded as an indication of the presence of fine ash floating in the atmosphere at the point of collection. The microscopical examinations also clearly indicated that the condition and kind of paving used on the streets in the vicinity of the point of collection had an important influence upon the composition of the solid materials detected in the atmosphere. In the case of tests made in the vicinity of streets paved with wood block, considerable quantities of wood fiber were detected in the residue from the filters. In fact, each particular kind of paving seemed to give off particles of dust, the composition of which, in general, corresponded to the composition of the paving material itself.

The materials noted by microscopical examination included colored fibers, hair, pollen, cinders, soot, bits of coal, bits of wood, particles of slag, mineral, animal and vegetable debris, and numerous other substances from a multitude of sources.

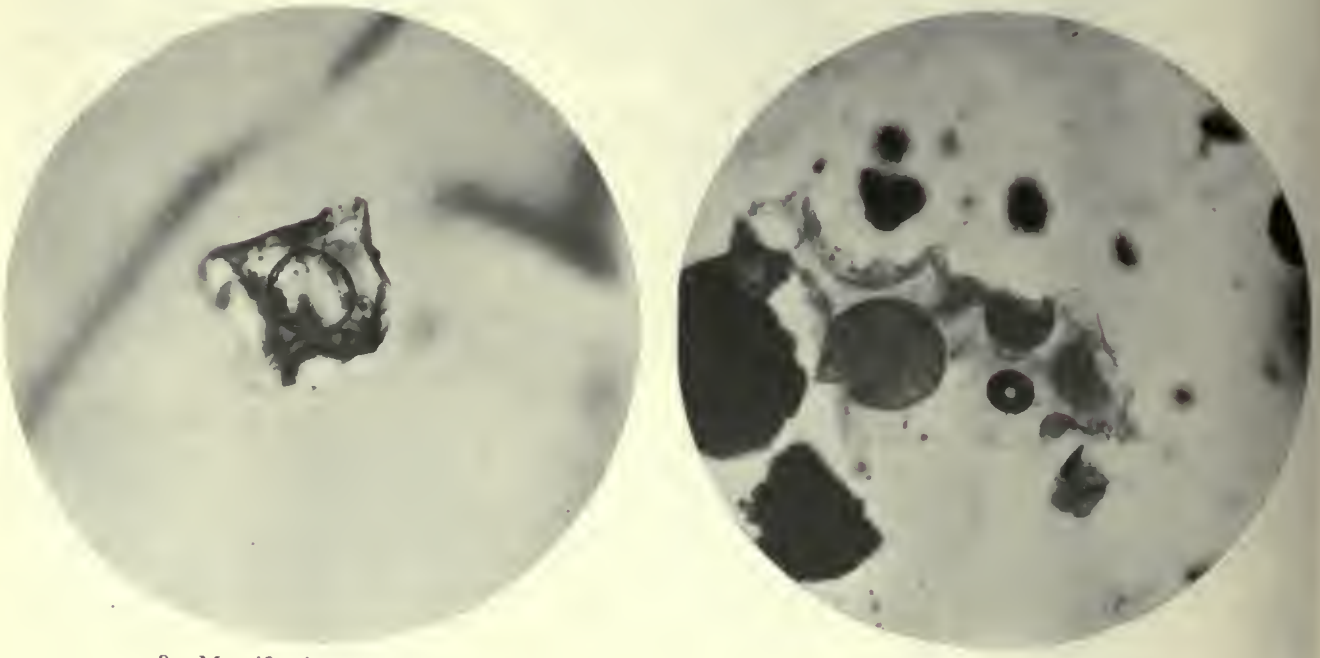
Photomicrographs were made of samples of the material collected at various points. These are shown as figs. 84 to 90, inclusive.

Photomicrographs Nos. 1 and 2 of fig. 84 show the appearance of material taken from the filter used in test No. 134, which was conducted at 90th Street and Mackinaw Avenue. An easterly wind prevailed at the time. No. 1 was made with a magnification of 200 diameters and No. 2 with a magnification of 140 diameters. It will be noted that certain particles of the material shown are transparent and resemble broken glass in their sharp outline. Photomicrograph No. 3 of fig. 84 shows the appearance of a fragment taken from the filter used in test No. 112, which was conducted at a point near the lake front in Grant Park. The magnification is 400 diameters, but



1. Magnification, 200 Diameters (Test No. 134)

2. Magnification, 140 Diameters (Test No. 134)



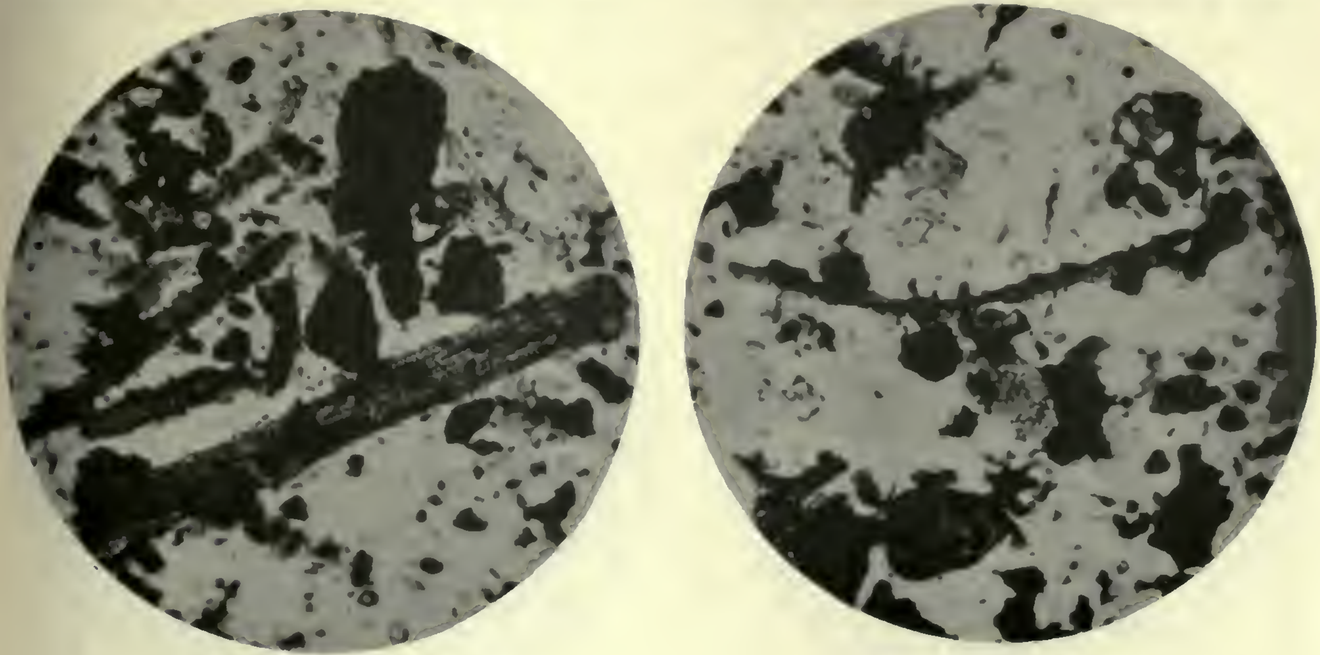
3. Magnification, 400 Diameters (Test No. 112)

4. Magnification, 325 Diameters

FIG. 84. PHOTOMICROGRAPHS OF SOLID PARTICLES COLLECTED BY MEANS OF FILTERS

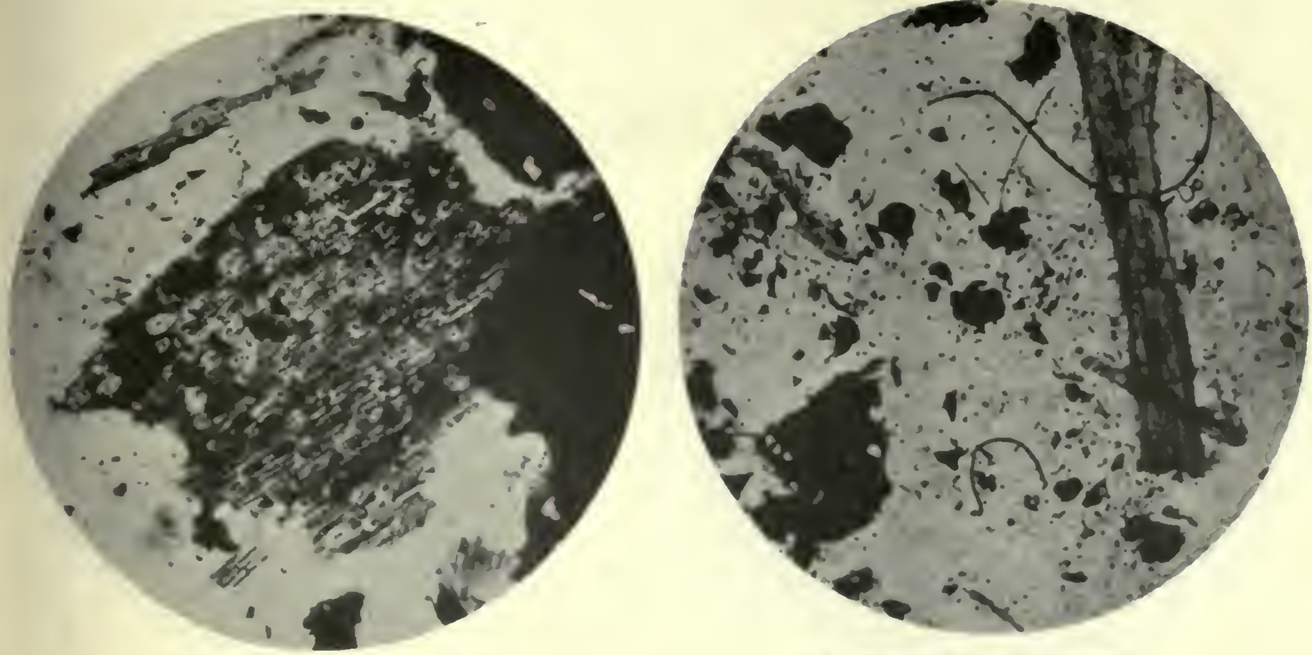
the substance presents the same general appearance as do some of the particles illustrated in photomicrographs Nos. 1 and 2. Photomicrograph No. 4 of fig. 84 shows the appearance of material collected at a point in the neighborhood of a steel plant. The magnification in this instance is 325 diameters. In all probability the glassy materials evident in all these samples consisted of very finely divided slag.

Photomicrographs Nos. 1 and 2 of fig. 85 show the appearance of materials collected in test No. 130, conducted at Chicago Avenue and



1. Magnification, 75 Diameters
(Test No. 130)

2. Magnification, 75 Diameters
(Test No. 130)

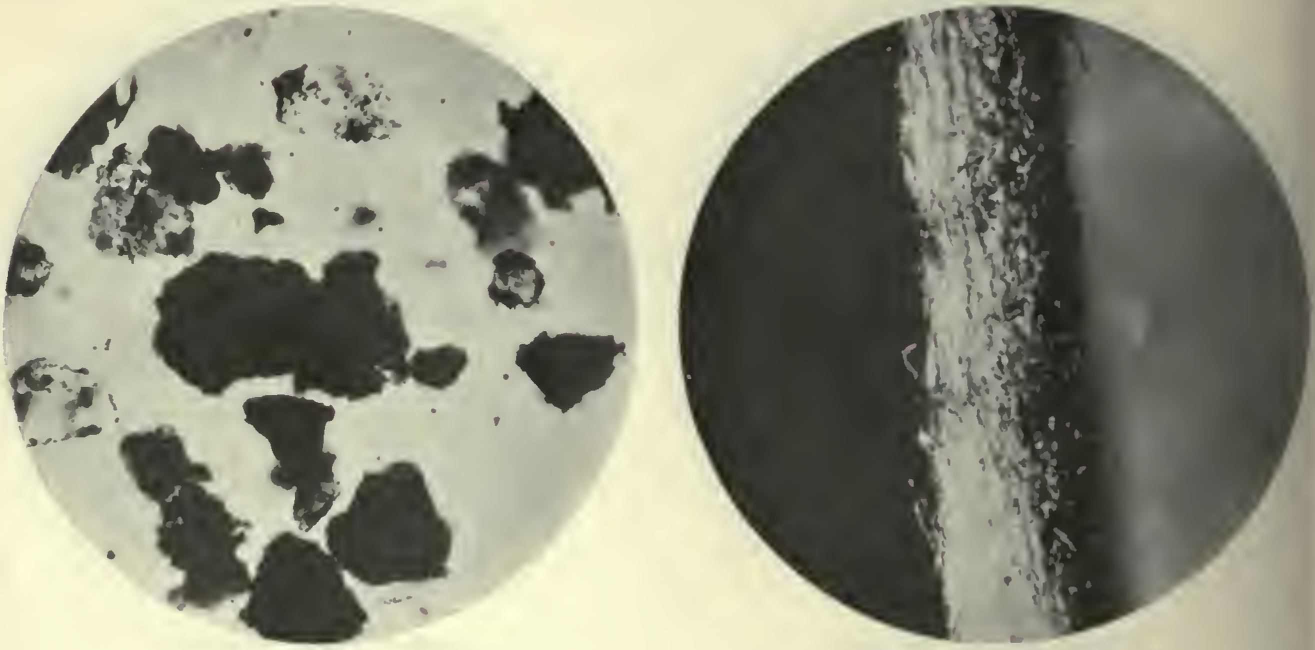


3. Magnification, 110 Diameters
(Test No. 92)

4. Magnification, 30 Diameters
(Test No. 102)

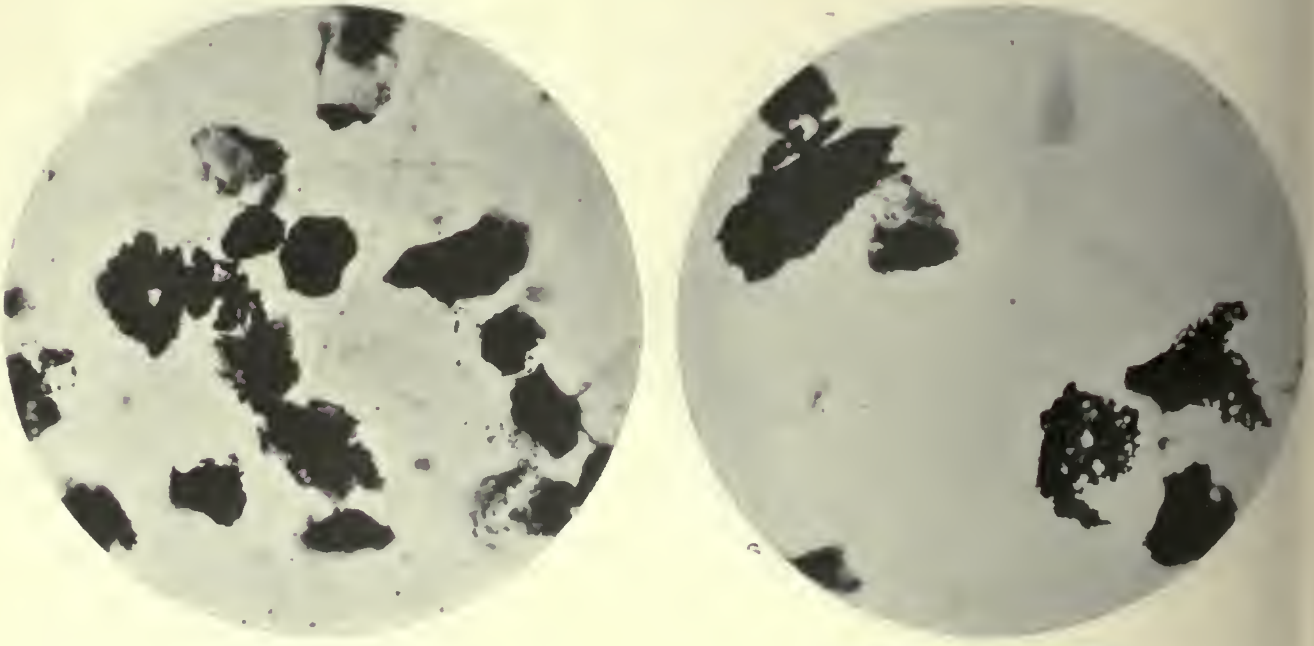
FIG. 85. PHOTOMICROGRAPHS OF SOLID PARTICLES COLLECTED BY MEANS OF FILTERS

Halsted Street. The atmosphere at the time of collection obviously contained considerable quantities of dust. The magnification in each case is 75 diameters. The presence of wood fibers, cinders, soot, ashes and considerable mineral debris is to be noted. Photomicrograph No. 3 of fig. 85 shows the appearance of material collected in test No. 92, which was conducted at a point on La Salle Street between Adams and Monroe Streets. The magnification is 110 diameters. The woody tissue present in this sample probably had its origin in the wood block paving on La Salle Street. Photomicrograph No. 4 of fig. 85 shows the appearance of material collected



1. Magnification, 240 Diameters
(Test No. 46)

2. Magnification, 240 Diameters
(Test No. 64)



3. Magnification, 240 Diameters
(Test No. 46)

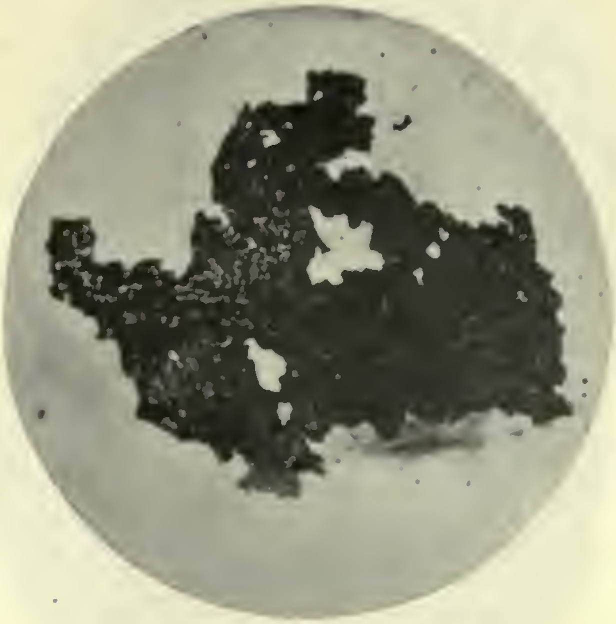
4. Magnification, 240 Diameters

FIG. 86. PHOTOMICROGRAPHS OF SOLID PARTICLES COLLECTED BY MEANS OF FILTERS

during test No. 102, which was conducted on Dearborn Street near Adams Street. The magnification is 30 diameters. This sample contained animal and vegetable fiber, woody tissue, cinders, soot and mineral debris.

Photomicrographs Nos. 1 and 3 of fig. 86 show the appearance of materials taken from the filters used in test No. 46, which was conducted at Union Avenue and 50th Street. The large particle shown in No. 3, with the white spot in the center, is soot. The particles showing a tendency to conchoidal outlines or fractures are bits of coal. The particles which present a translucent appearance consist of mineral matter to which, in some cases, particles of soot are adhering. The faintly outlined fibers are cotton fibers from the filter.

1. Magnification, Not Recorded



2. Magnification, Not Recorded

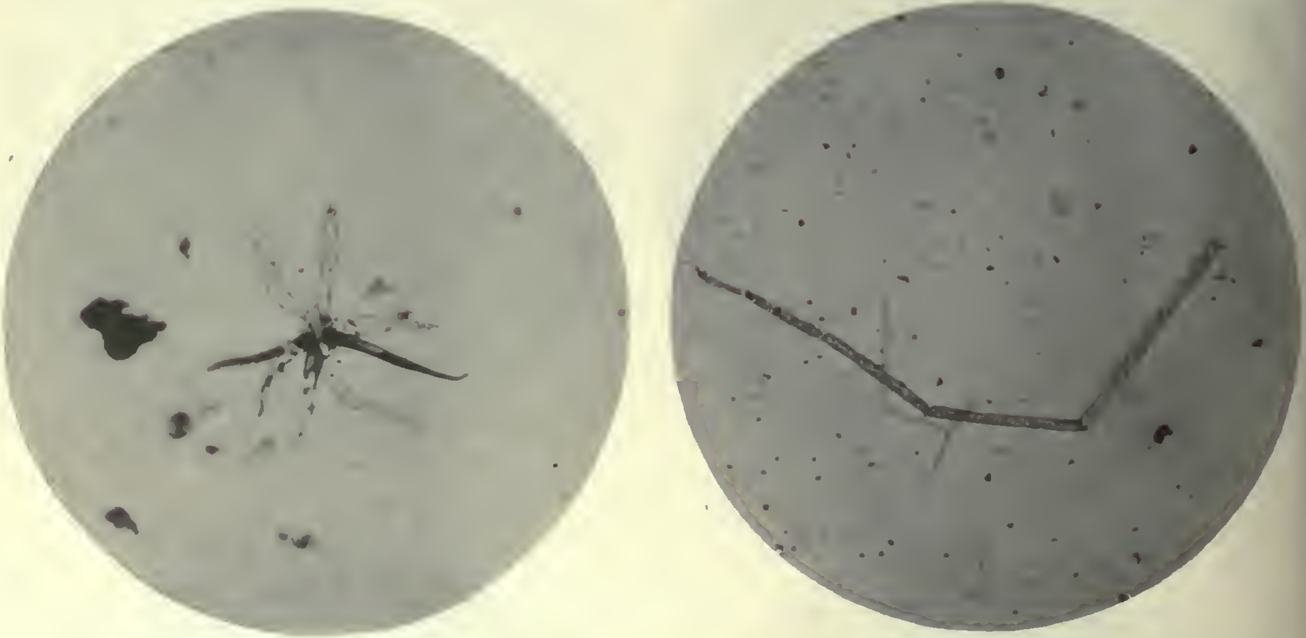
3. Magnification, Not Recorded

4. Magnification, Not Recorded

FIG. 87. PHOTOMICROGRAPHS OF SOLID PARTICLES COLLECTED BY MEANS OF FILTERS

Photomicrograph No. 2 of fig. 86 shows the appearance of a part of the filter used in test No. 64, conducted at Chicago Avenue and Halsted Street. The lighter half shows the appearance of the inside of the filter shell. The penetration of the finely divided solids into the close grained texture of the filter paper is shown by the dark appearance of the right hand portion of the shell, which appears vertically across the center of the photomicrograph. This illustration serves to show the efficiency of this type of filter for removing all of the solid materials from the air which passes through it. Photomicrograph No. 4 of fig. 86 shows the appearance of unbroken particles of soot which were collected from various filters. It was found very difficult to mount these specimens for photographing without disintegrating them into the ultra-microscopic particles of which they are aggregates.

Photomicrograph No. 1 of fig. 87 shows an animal hair, vegetable fiber, coarse mineral debris and ash. Photomicrograph No. 2 of fig. 87 shows a mass of vegetable and organic tissue highly magnified. Photomicrograph No. 3 of fig. 87 shows an animal hair, while No. 4 shows coarse mineral debris. The thread-like substance extending



1. Magnification, Not Recorded
(Test No. 138)

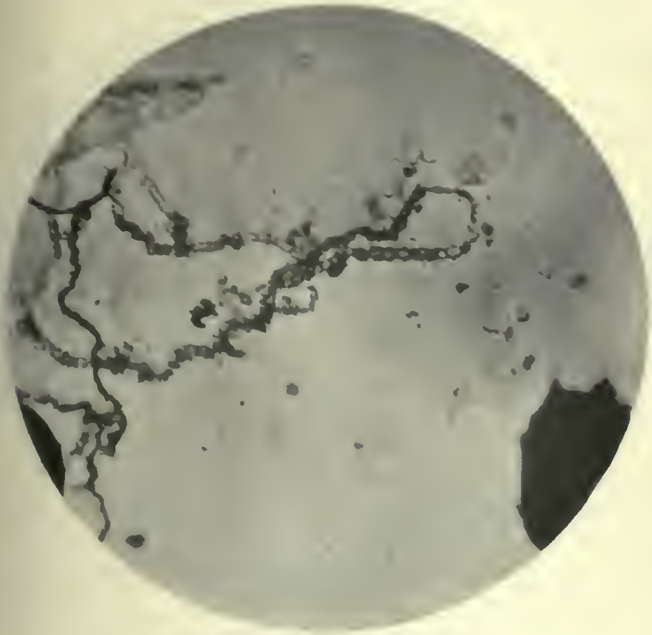
2. Magnification, Not Recorded
(Test No. 152)

3. Magnification, Not Recorded

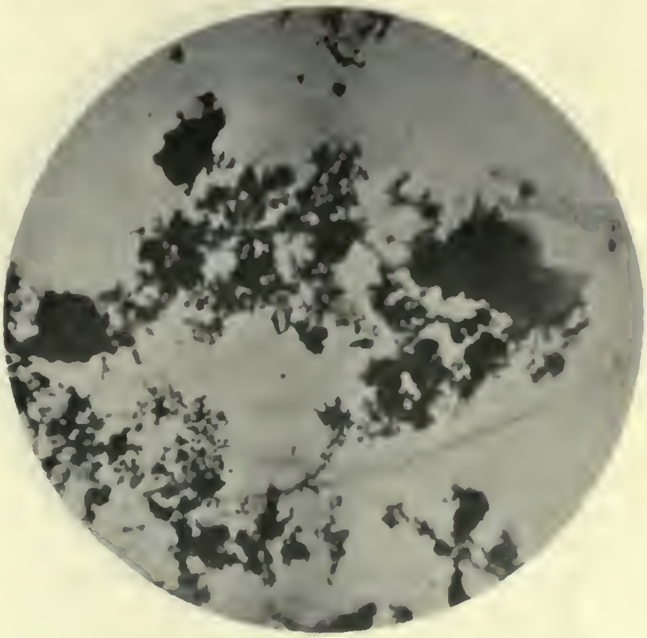
FIG. 88. PHOTOMICROGRAPHS OF SOLID PARTICLES COLLECTED BY MEANS OF FILTERS

across the photomicrograph is hair and the substance resembling a starfish is a bit of vegetable fiber.

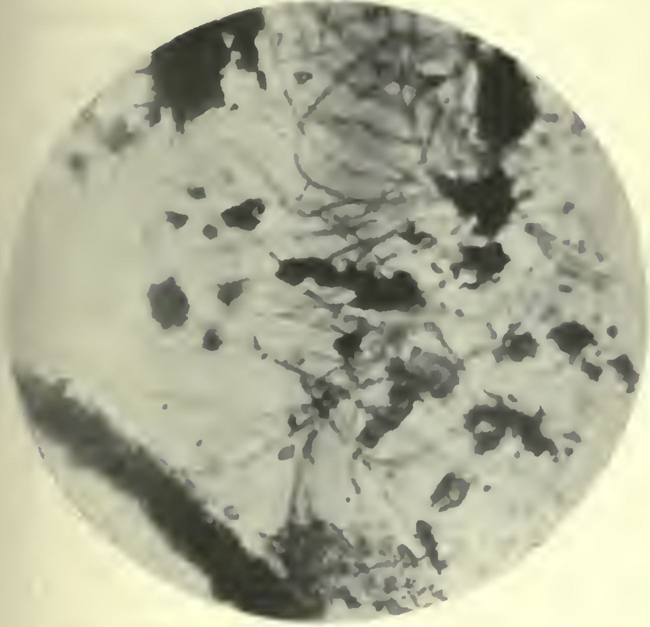
Photomicrograph No. 1 of fig. 88 shows the characteristic appearance of vegetable fiber. The material was collected in test No. 138, which was conducted on Clark Street near the postoffice. Photomicrograph No. 2 of fig. 88 shows the appearance of a sample of material taken from the filter used in night test No. 152, conducted in Humboldt Park. Part of an insect and a small quantity of very finely divided mineral debris are shown. Photomicrograph No. 3 of fig. 88 shows pollen collected in some of the tests.



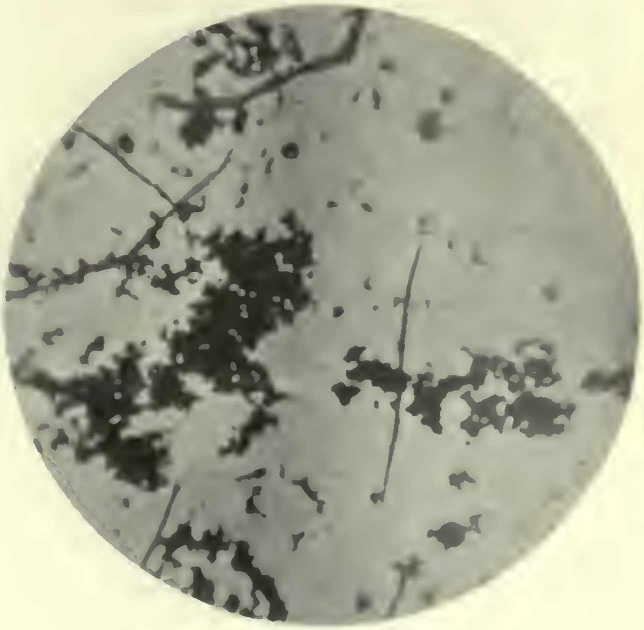
1. Magnification, 140 Diameters
(Test No. 51)



2. Magnification, 140 Diameters
(Test No. 53)



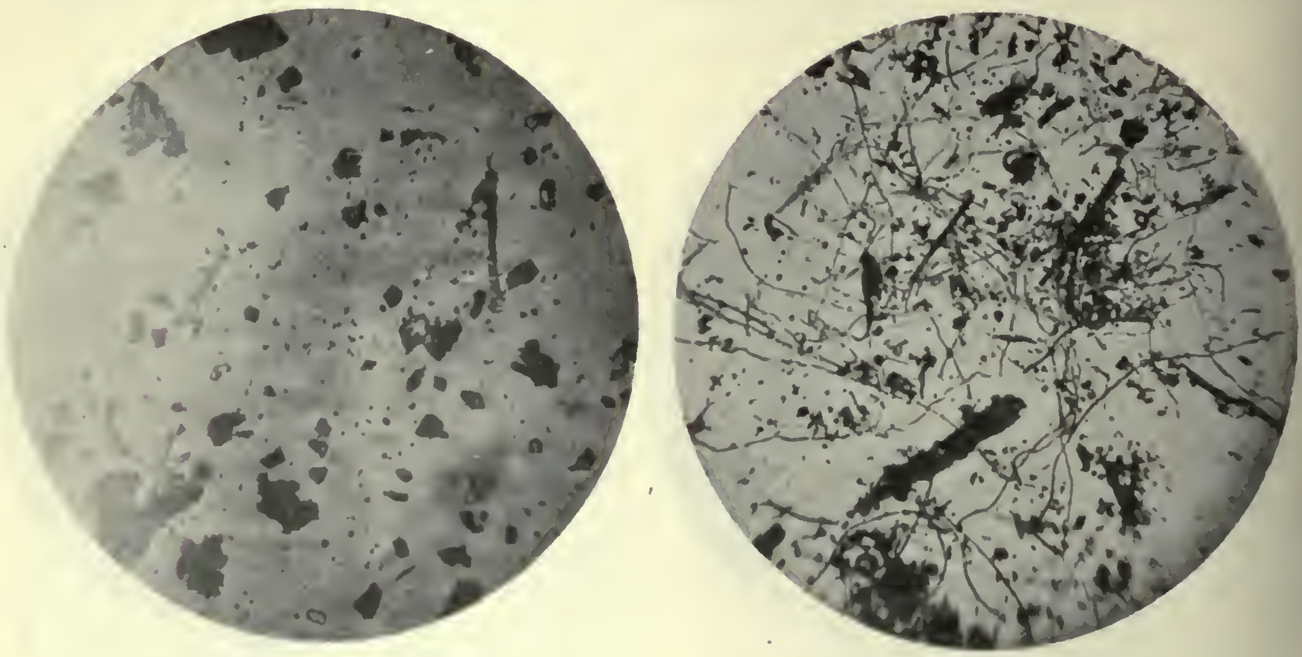
3. Magnification, 140 Diameters
(Test No. 33)



4. Magnification, 140 Diameters
(Test No. 53)

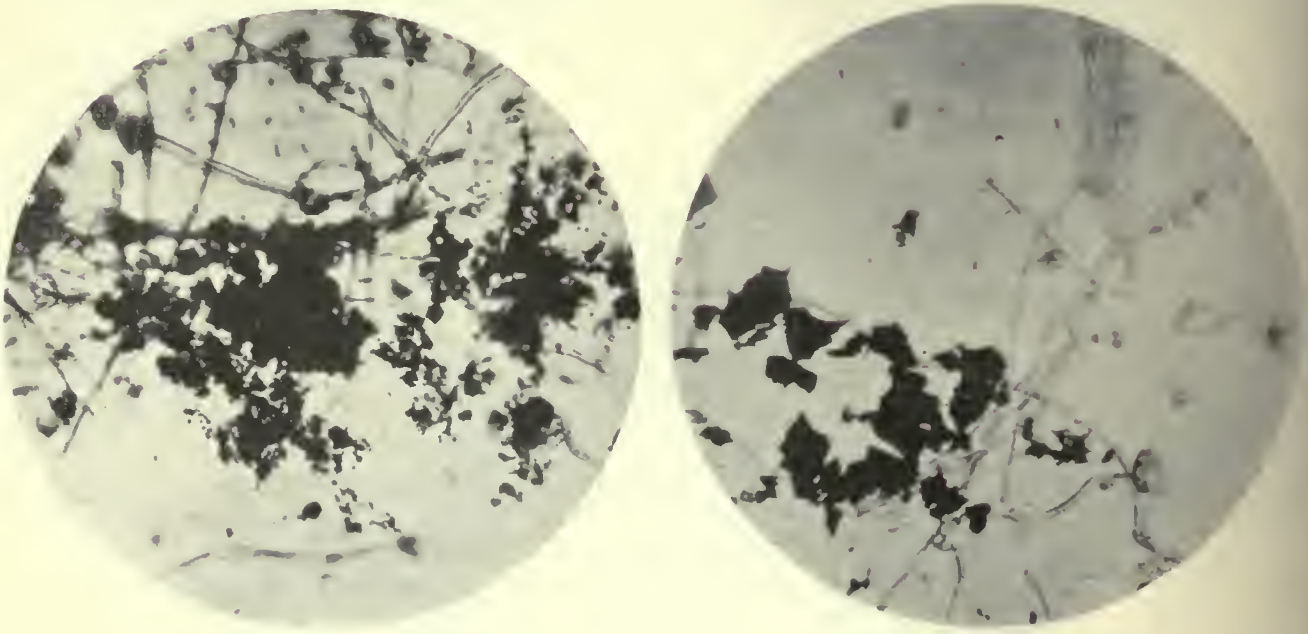
FIG. 89. PHOTOMICROGRAPHS OF SOLID PARTICLES COLLECTED BY MEANS OF FILTERS

Photomicrograph No. 1 of fig. 89 shows the appearance of mold taken from the filter used in night test No. 51, conducted at Oakley Avenue and 18th Street. Photomicrograph No. 2 of fig. 89 shows the appearance of bits of crushed cinder, mineral matter and vegetable tissue collected in test No. 53. No. 3 shows pieces of coal, cinders, soot, ash, vegetable tissue and cotton fiber, all of which were taken from the filter used in test No. 33, conducted at Halsted and 39th streets. Photomicrograph No. 4 of fig. 89 shows the appearance of material collected in test No.



1. Magnification, 140 Diameters
(Test No. 37)

2. Magnification, 140 Diameters
(Test No. 44)



3. Magnification, 140 Diameters
(Test No. 53)

4. Magnification, 140 Diameters
(Test No. 43)

FIG. 90. PHOTOMICROGRAPHS OF SOLID PARTICLES COLLECTED BY MEANS OF FILTERS

53. It is similar to that shown in photomicrograph No. 2. The magnification of all photomicrographs in fig. 89 is 140 diameters.

Photomicrograph No. 1 of fig. 90 shows the appearance of material collected in test No. 37, conducted at Washington Boulevard and Halsted Street. The illustration shows the presence of mineral debris and vegetable fibers. Photomicrograph No. 2 of fig. 90 shows the appearance of material collected in night test No. 44, conducted at Marshfield Avenue and 45th Street. Cotton fiber from the filter, finely divided soot, mineral debris, bits of wood, and vegetable fiber are shown. Photomicrograph No. 3 of fig. 90 shows the appearance of materials collected in test No. 53, conducted at Kinzie and Clinton streets. Photomicrograph No. 4 of fig. 90 shows the appearance of a bit of broken coal collected in night test No. 43, at a point near Emerald Avenue and 46th Street.

The results of the microscopical examinations described in the preceding paragraphs and illustrated by the photomicrographs presented, serve to emphasize the fact that much of the dust and solid materials present in the atmosphere of Chicago is of non-fuel origin. A study of related facts seems to indicate that approximately one-third of such pollution is of non-fuel origin.

113.17 Solid Constituents of the Atmosphere as Indicated by Reports of Investigations in Other Cities: Reported values with reference to the solid materials contained in the air of other cities are, in nearly all cases, expressed in units which are not comparable with the values determined by the analyses in Chicago. In most other cities where investigations have been made, the purpose has been to measure the quantity of material deposited per unit of area in a given time. Only in the case of the investigation conducted at Cleveland were the results expressed in milligrams per cubic meter. The values reported for Cleveland varied from 1.5 to 39.9 milligrams per cubic meter, the average being 14.3, or about 17 times that of the analyses in Chicago. It is obvious, also, that the values for other cities, although not directly comparable, are relatively high.

113.18 Nitrous Acid (HNO_2) in the Atmosphere as Disclosed by Air Analyses: Determinations for nitrous acid were made in connection with the 160 analyses of air samples, the process employed being that hereinbefore described (section 113.12). The averages of the values obtained from both day and night tests for each class of district are presented as table CXXVI.

TABLE CXXVI. AVERAGE VALUES FOR NITROUS ACID (HNO_2) AS DETERMINED BY AIR ANALYSES

Milligrams per Cubic Meter					
Districts	No. Tests	Nitrous Acid (HNO_2)	Districts	No. Tests	Nitrous Acid (HNO_2)
Country	6 Day	0.00153	Mixed	20 Day	0.00854
Park	20 Day	0.00383	Residence	5 Night	0.00547
	4 Night	0.00882		All	0.00901
	All	0.00466			
Playground	6 Day	0.00749	Boulevard	10 Day	0.00603
	3 Night	0.00615		5 Night	0.00306
	All	0.00704		All	0.00534
Residence	24 Day	0.00526	Railroad	30 Day	0.00787
	9 Night	0.00909		14 Night	0.00541
	All	0.00630		All	0.00722
Industrial	26 Day	0.00691	Loop	26 Day	0.01576
	9 Night	0.00589		7 Night	0.00909
	All	0.00664		All	0.01414

A study of the results presented in table CXXVI indicates that the average values for nitrous acid contained in samples collected during the day exceeded the average for samples collected during the night in all classes of districts except the park and residence classes. The reason for this difference probably lies in the fact that electricity is extensively used for arc lighting at night in the park and residence districts. On the other hand, the day values for nitrous acid in the loop district exceed the night values, a condition probably due to the fact that the quantity of electricity used for such purposes as arc lighting, and propelling electric surface and elevated cars, is considerably less during the night than during the day. All uses of electricity in which an arc is produced intermittently or continuously serve to produce nitrous acid.

The values for nitrous acid at a number of locations were lower for the day tests than for the night tests. Most of these belonged to the park and residence classes. In one location only, in the park and residence classes, did the day values exceed the night values, this exception being in the case of a point of collection which was included in both of these classes of location. For all the other classes of location, there were only four instances in which the night values for nitrous acid exceeded the day values, one of these being in the case of a location near the lake front.

113.19 Nitrous Acid (HNO_2) Content of the Atmosphere as Indicated by Reports of Investigations in Other Cities: The values reported for other cities, with reference to the nitrous acid content of the atmosphere, are not comparable with the results of the analyses conducted in Chicago.

113.20 Ammonia (NH3) Present in the Atmosphere of Chicago as Disclosed by Air Analyses: Determinations for ammonia were made in connection with the analyses of air samples according to the process hereinbefore described (section 113.12). The averages of the values obtained from both the day and the night tests for each class of district are presented as table CXXVII.

From the values presented in table CXXVII, it may be noted that the average results for ammonia in samples collected during the day did not cover as wide a range of values as did the results of the night tests. The ammonia content of the atmosphere was generally higher in playground, residence and industrial districts than in other localities. In general, the ammonia content increased directly as the distance of the point of collection from the loop district. Two explanations are offered for the relatively low values for ammonia in the loop district; first, the presence of large quantities of sulphur and other acids in the loop district may be responsible for the formation of certain salts which could easily be intercepted by the filter and not admitted into the solutions, the presence of such salts being noted in qualitative tests; second, there is less organic matter, the decaying of which produces ammonia, present in the centers of intense business activity, such as the loop district, than is generally found in residential or park districts. In the case of industrial districts, ammonia may arise both from the decay of organic matter and from certain industrial activities in which it is used or produced.

TABLE CXXVII. AVERAGE VALUES FOR AMMONIA (NH_3) AS DETERMINED BY AIR ANALYSES

Milligrams per Cubic Meter					
Districts	No. Tests	Ammonia (NH_3)	Districts	No. Tests	Ammonia (NH_3)
Country	6 Day	0.00554	Mixed Residence	20 Day	0.00835
Park	20 Day	0.00802		5 Night	0.01904
	4 Night	0.01276		All	0.01049
	All	0.00881			
Playground	6 Day	0.01035	Boulevard	10 Day	0.00791
	3 Night	0.01615		5 Night	0.01325
	All	0.01117		All	0.00969
Residence	24 Day	0.00916	Railroad	39 Day	0.00728
	9 Night	0.02243		14 Night	0.01029
	All	0.01278		All	0.00807
Industrial	26 Day	0.01160	Loop	26 Day	0.00556
	9 Night	0.02237		7 Night	0.00689
	All	0.01437		All	0.00585

It should be noted that the ammonia values varied directly with the temperature, the lower values being recorded at the lower temperatures. All of the night tests, for which records are given, were made at temperatures above 53 degrees Fahrenheit, so that the effect of the temperature in the case of night values is not so apparent as in the case of day values; the temperature at the time of day tests varied from 9 degrees Fahrenheit to the high summer values.

113.21 Ammonia (NH3) Content of the Atmosphere as Disclosed by Reports of Investigations in Other Cities: The reported values of the ammonia content of the atmosphere of other cities appear to be many times higher than the values determined by the air analyses in Chicago, although results are generally expressed in units which are not directly comparable with those employed in Chicago.

113.22 Chlorin (Cl) in the Atmosphere as Determined by Air Analyses: Determinations for chlorin were made in connection with the analyses of air samples, the process employed being that hereinbefore described (section 113.12). The average values obtained from both the day and the night tests in each class of location are presented as table CXXVIII.

TABLE CXXVIII. AVERAGE VALUES FOR CHLORIN (Cl) AS DETERMINED BY AIR ANALYSES

Milligrams per Cubic Meter					
Districts	No. Tests	Chlorin (Cl)	Districts	No. Tests	Chlorin (Cl)
Country	6 Day	0.0253	Mixed Residence	20 Day	0.1438
Park	20 Day	0.0715		4 Night	0.1012
	4 Night	0.0375		All	0.1291
	All	0.0658			
Playground	6 Day	0.0908	Boulevard	10 Day	0.1557
	3 Night	0.0844		5 Night	0.1381
	All	0.0887		All	0.1498
Residence	24 Day	0.0715	Railroad	36 Day	0.1490
	9 Night	0.1148		14 Night	0.1146
	All	0.0833		All	0.1394
Industrial	26 Day	0.1291	Loop	26 Day	0.2434
	9 Night	0.1147		7 Night	0.0935
	All	0.1254		All	0.2116

A study of the results presented by table CXXVIII indicates that, in all classes of districts except the residence class, the values for chlorin varied inversely as the distance of the point of collection from the loop district; or, in other words, that the content of chlorin detected in the atmosphere was higher near the centers of activity than in the outlying districts. The amount of chlorin present in the samples which were collected during the day was larger than that present in the samples collected during the night, in all classes of districts except the residence class.

There were 14 locations at which the day results for chlorin were lower than the night results. Six of this number were residence locations; one was a point on the lake front at which an east wind prevailed at the time of collection; one was a park location; two were industrial locations; two were railroad locations; and two were loop locations. There were only eight night tests conducted in residence districts, and of the three which did not yield lower results for the day than for the night, one test showed no chlorin either for night or for day and the other two showed only slightly higher values for the day than for the night.

113.23 Chlorin (Cl) Content of the Atmosphere as Disclosed by Reports of Investigations in Other Cities: Data from which a comparison may be drawn between the chlorin content of Chicago's atmosphere and that of the atmosphere of other cities are not available.

113.24 Amount of Sulphuric Acid (H_2SO_4) Present in the Atmosphere as Determined by Air Analyses: Determinations for sulphuric acid were made in connection with the analyses of air samples according to the process hereinbefore described (section 113.12). The values which were thus obtained for both the night and the day tests for each class of location are presented as table CXXIX.

TABLE CXXIX. AVERAGE VALUES FOR SULPHURIC ACID (H_2SO_4) AS DETERMINED BY AIR ANALYSES

Milligrams per Cubic Meter					
Districts	No. Tests	Sulphuric Acid (H_2SO_4)	Districts	No. Tests	Sulphuric Acid (H_2SO_4)
Country	6 Day	0.069	Mixed Residence		
Park	20 Day	0.218		20 Day	0.652
	4 Night	0.219		5 Night	0.518
	All	0.217		All	0.625
Playground	6 Day	0.477	Boulevard	10 Day	0.639
	3 Night	0.354		5 Night	0.594
	All	0.439		All	0.624
Residence	24 Day	0.364	Railroad	37 Day	0.728
	9 Night	0.560		14 Night	0.560
	All	0.417		All	0.681
Industrial	26 Day	0.565	Loop	26 Day	1.104
	9 Night	0.379		7 Night	0.423
	All	0.517		All	0.959

The content of sulphuric acid in the atmosphere, as shown by the results of day tests, was generally higher in the vicinity of the loop district than in the outlying districts. The day values in most districts were higher than the corresponding night values, an exception to this rule occurring in the case of the residence districts. The fact that the night values in the residence districts were generally higher than the day values may be accounted for by the fact that the relative humidity is generally higher and the wind velocity lower at night than during the day. This condition of the atmosphere causes a dampness and stagnation, so that the sulphuric acid is retained instead of being dissipated as is the case with a more pronounced wind movement or a lower humidity. In the case of railroad locations it may be noted that the values for night tests were generally lower than those for day tests, a condition which may be attributed to the relative traffic activities of the day and the night, the night test usually covering the period from midnight to 7:00 A.M., during which comparatively few trains are in motion. In the case of the loop district the night values for sulphuric acid were considerably lower than the day values, a condition probably due to the fact that there is, on the whole, a lower rate of fuel consumption during the night than during the day. Of the nine tests made for sulphuric acid in the residence districts at night, seven showed higher values than the corresponding day tests. Of these seven, four were conducted at a time when the humidity and wind velocity were lower than for the corresponding day tests, and three were taken under weather conditions essentially the same as those obtaining for the corresponding day tests.

113.25 Sulphuric Acid (H_2SO_4) Content of the Atmosphere as Disclosed by Reports of Investigations in Other Cities: The reported values for the sulphuric acid content of the atmosphere of other cities are materially higher than those for Chicago's atmosphere, except in the case of Hamburg, Germany, where the values are about one-tenth as high as those for Chicago.

113.26 Carbon Dioxid (CO_2) in the Atmosphere as Determined by Air Analyses: The apparatus by means of which determinations for carbon dioxid were made was not available until August 20, 1912. The results obtained by the apparatus employed previous to that date were incorrect, the values being considerably lower than those subsequently obtained with the more improved apparatus. Determinations for carbon dioxid were made in a total of 120 tests, 93 of which were conducted during the day and 27 during the night. The average values obtained from these determinations for both the day and night tests in each class of location are presented as table CXXX.

A study of values presented by table CXXX indicates a tendency for the content of carbon dioxid in the atmosphere, as determined by the day tests, to vary directly as the distance of the point of collection from the loop district. In general, this variation corresponds to that noted in the case of other substances. The night values for carbon dioxid do not seem to follow any definite rule with reference to the location of the point of collection, the highest average night values having been noted in the residence districts. As compared with the day values, the night values decrease in the centers of business activity

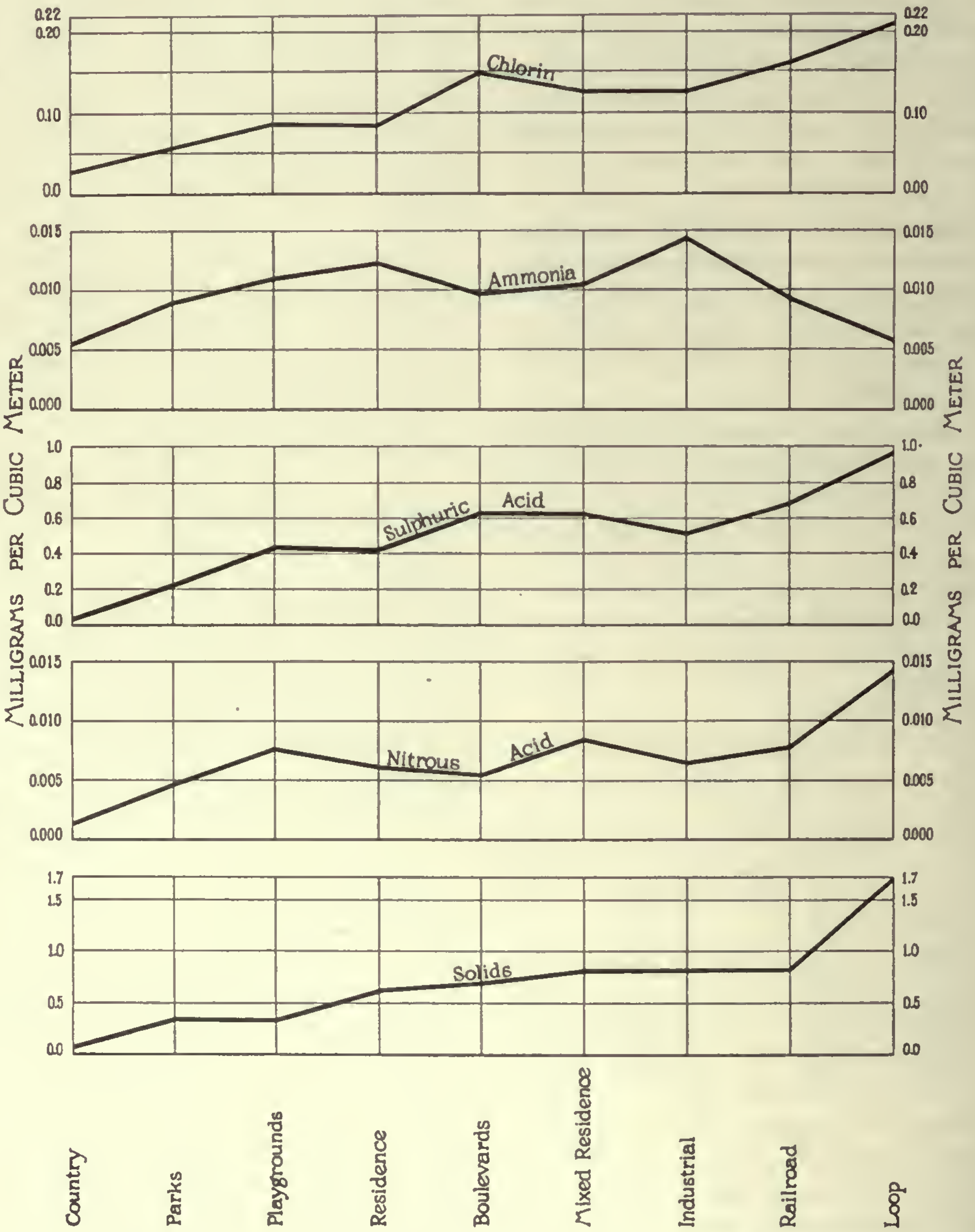


FIG. 91. AVERAGE RESULTS OF ANALYSES OF SAMPLES OF AIR

TABLE CXXX. AVERAGE VALUES FOR CARBON DIOXID (CO_2) AS DETERMINED BY AIR ANALYSES

Parts per 10,000

Districts	No. Tests	Carbon Dioxid	Districts	No. Tests	Carbon Dioxid
Country	6 Day	3.17	Mixed Residence	15 Day	3.18
				4 Night	3.32
				All	3.21
Park	8 Day	2.96	Boulevard	7 Day	3.44
	4 Night	3.63		3 Night	3.22
	All	3.18		All	3.37
Playground	2 Day	3.44	Railroad	32 Day	3.38
	2 Night	3.23		40 Night	3.34
	All	3.18		All	3.37
Residence	16 Day	3.04	Loop	27 Day	3.81
	4 Night	3.67		6 Night	3.40
	All	3.16		All	3.74
Industrial	19 Day	3.30			
	7 Night	3.54			
	All	3.36			

and increase in the residence districts, thereby indicating a tendency to follow the movement of the people. It is probably true that the rate of combustion of fuel in the centers of business activity is lower during the night than during the day, while in the residence districts the reverse is true.

The highest value for carbon dioxid noted, in the total of 120 tests, was 4.72 parts per 10,000, this being the average of the several determinations made in the test in question. It is apparent, therefore, that the range of values is comparatively slight, the lowest result being 2.44 parts per 10,000. In no case was carbon dioxid found present in a sufficient amount to cause the slightest injury or inconvenience to persons.

113.27 Carbon Dioxid (CO2) Content of the Atmosphere as Disclosed by Reports of Investigations in Other Cities: The carbon dioxid content of the atmosphere as reported by many cities does not appear to vary materially, the values reported for other cities corresponding very closely to those resulting from the analyses in Chicago.

113.28 Summary of Results: Determinations were made in a total of 160 tests for solids, nitrous acid, ammonia, chlorin and sulphuric acid. Determinations were made in a total of 120 tests for carbon dioxid. The results for each of these substances have been presented in the preceding sections. With the exception of ammonia, the general tendency of all substances is to increase in value as the loop district is approached. A summary of the averages of the results of all the tests, from which comparisons may be drawn between the values for the different substances and for different classes of district, is given as table CXXXI.

TABLE CXXXI. SUMMARY OF RESULTS OF DETERMINATIONS FOR SOLIDS, NITROUS ACID, AMMONIA, CHLORIN, SULPHURIC ACID AND CARBON DIOXID

Districts	Milligrams per Cubic Meter					Carbon Dioxid (CO_2) Parts per 10,000
	Solids	Nitrous Acid (HNO_2)	Ammonia (NH_3)	Chlorin (Cl)	Sulphuric Acid (H_2SO_4)	
1	2	3	4	5	6	7
Country						
No. of tests	6	6	6	6	6	6
Average	0.049	0.00153	0.00554	0.0253	0.060	3.17
Park						
No. of tests	24	24	24	24	24	12
Average	0.330	0.00466	0.00881	0.0658	0.217	3.15
Playground						
No. of tests	9	9	9	9	9	4
Average	0.327	0.00704	0.01117	0.0887	0.430	3.18
Residence						
No. of tests	33	33	33	33	33	20
Average	0.618	0.00630	0.01278	0.0833	0.417	3.16
Industrial						
No. of tests	33	35	35	35	35	26
Average	0.826	0.00664	0.01437	0.1254	0.517	3.36
Mixed Residence						
No. of tests	25	25	25	24	25	19
Average	0.848	0.00801	0.01049	0.1291	0.625	3.21
Boulevard						
No. of tests	14	15	15	15	15	10
Average	0.697	0.00534	0.00960	0.1498	0.624	3.37
Railroad						
No. of tests	50	53	53	50	51	42
Average	0.821	0.00722	0.00807	0.1394	0.681	3.37
Loop						
No. of tests	33	33	33	33	33	33
Average	1.689	0.01414	0.00585	0.2116	0.950	3.74

The average values of solids, nitrous acid, ammonia, chlorin and sulphuric acid, for each class of location, are shown in relation to each other in fig. 91.

A study of these results does not yield any very significant facts regarding the relationship between the different substances. For instance, nitrous acid and ammonia do not seem to bear any special relation to each other. In some instances the values for these two substances may be parallel in a considerable number of tests, while in other instances an increasing value for nitrous acid may accompany a decreasing value for ammonia. The ammonia results, when presented diagrammatically in connection with recorded temperatures, indicate a tendency to vary directly with the temperature. In general, therefore, it may be said that the amount of ammonia present in the atmosphere depends largely upon the temperature. Certain exceptions were noted to this general rule, as for instance, in test No. 139, in which a comparatively low ammonia value was recorded at a relatively high temperature. The values for nitrous acid, particularly in the case of the loop tests, show a similar variation with temperature. This relation does not seem to exist, however, in tests made at night or during a rain.

113.29 Conclusions to be Drawn from the Results of Air Analyses: The results obtained from the numerous chemical and physical analyses of air samples hereinbefore described justify the following conclusions:

1. In general, those polluting constituents of the atmosphere which are regarded as being most objectionable consist largely of solid particles which serve to soil or injure buildings and materials of every sort. These constituents have their origin largely in the combustion of fuel, and appear in the form of distillates of coal, unconsumed carbonaceous material or ash. Ash in the atmosphere is practically devoid of color and its presence is not readily identified. It is not as detrimental or apparent in its effects upon material objects as are the sooty or carbonaceous materials.

2. The quantity of solid materials in the atmosphere of Chicago varies from 0.321 to 1.958 milligrams per cubic meter. Values of record for other cities are not numerous and, except in a few cases, are expressed in units which will not permit them to be compared with those determined by tests in Chicago. In Cleveland, values have been determined which vary from 1.5 to 39.9 milligrams per cubic meter, the average being 14.3 milligrams.

3. The solid materials or particles present in the atmosphere of Chicago include not only solid products of combustion, but also mineral, vegetable and animal debris. The evidence based upon atmospheric analyses is to the effect that all sources of dust contribute to the pollution of the atmosphere.

4. The content of carbon dioxid in the atmosphere of cities, as disclosed by the reports of many investigations, does not appear to vary materially. The values determined for this substance, from samples taken of Chicago's atmosphere, correspond very closely to those reported for other large cities.

5. Carbon monoxid, while in itself a poisonous gas, does not ordinarily constitute an important element in atmospheric pollution. No determinations of this gas were made in connection with the air analyses in Chicago. Values resulting from tests conducted in Paris and in Berlin indicate the presence of only minute quantities of it.

6. The ammonia content of the atmosphere of Chicago is small. The values reported for other cities are many times greater than those for Chicago.

7. Chlorin is not present in the atmosphere of Chicago in sufficient quantities to have any significance except as an indication of local conditions. Data from which comparisons may be drawn between the chlorin content of Chicago's atmosphere and that of other cities are not available.

8. The gaseous compounds of sulphur are products of combustion, and in the atmosphere of Chicago they vary from a minimum average of 0.217 to a maximum average of 1.104 milligrams per cubic meter. The values reported for other cities, so far as obtainable, are materially higher, except in the case of Hamburg, Germany.

9. Sulphur compounds, which eventually are converted into sulphuric acid, are, from the standpoint of atmospheric pollution, the most objectionable gaseous products of combustion. Sulphuric acid tends to exert an important influence in the disintegration of building materials of all kinds, and produces deleterious effects upon furnishings, clothing and merchandise.

10. With reference to the geographical distribution of polluting substances in Chicago's atmosphere, it may be stated conclusively that the pollution is greatest in those localities where the greatest industrial activities prevail. The atmosphere in the loop district and in the neighborhood of railroad terminals is more seriously polluted than that of outlying districts.

11. A comparison of the results of the Committee's investigation with those obtained in other cities indicates that the degree of pollution present in Chicago's atmosphere is not greater than that of most other metropolitan centers; on the contrary, the atmosphere of Chicago is, on the whole, freer from polluting constituents than is the atmosphere of many other of the world's large cities.

12. The polluting constituents of the atmosphere have their origin in many kinds of industrial activity. The combustion of fuel is responsible for only a portion of the polluting substances present in the air.

114. CONCLUSIONS AS TO THE NECESSITY FOR THE ELECTRIFICATION OF CHICAGO'S RAILROAD TERMINALS AS A MEANS IN SMOKE ABATEMENT

SYNOPSIS: The Committee's investigations reported in the preceding chapters have had for their purpose the determination of the extent to which products of combustion are responsible for atmospheric pollution in Chicago. In these studies particular attention has been directed to the contribution of the steam locomotive to such pollution. It has been recognized that, if the elimination of the steam locomotive from Chicago would bring about an appreciable reduction in atmospheric pollution, electrification could be urged as a means in smoke abatement. This chapter summarizes the results of the Committee's studies relating to smoke and atmospheric pollution and considers the significance of the facts in their relation to the proposal to electrify Chicago's railroad terminals.

114.01 **The Proposal:** The elimination of the steam locomotive from Chicago, as a means in smoke abatement, has been many times proposed. Sources from which the proposal has originated have changed from time to time. It has been discussed by various clubs, it has been the subject of many addresses, and it has been studied and reported upon by expert committees. The underlying purpose has always been that of smoke abatement. Its consideration at once raises the question as to what would be accomplished in smoke abatement by the means proposed. Upon this point, the investigations of the Committee permit a quantitative response.

114.02 **Substitutes for the Steam Locomotive:** Any proposal to eliminate the steam locomotive from the railroad terminals of Chicago presupposes the substitution of some other form of power. It is important, first, to consider what substitutes are available at the present time.

The various forms of self-contained motive-power units, such as the internal combustion locomotive, the compressed air locomotive, the hot water locomotive and the electric storage battery locomotive, have been studied, and the extent to which each form is likely to prove serviceable under conditions prevailing in Chicago has been made the subject of a careful analysis (chapter 204). A general conclusion, based upon an extensive study of this aspect of the subject, is to the effect that there is available at this time no form of locomotive, carrying its own power, capable of handling all the traffic of the Chicago railroad terminals, which could be substituted for the steam locomotive, and there is no prospect of the immediate development of any such locomotive. The elimination of the steam locomotive from the railroad terminals of Chicago would therefore, under present conditions, necessitate the introduction of electric locomotives energized from a fixed power station through some form of continuous contact system; that is, it would necessitate the complete electrification of the terminals.

The significance of the proposal to electrify the railroad terminals of Chicago, as it appears in the extent and variety of service to be performed, in the character of the technical problems to be solved, in the costs involved and in the operating results to be secured thereby, is such as to justify most careful inquiry before any plan for complete electrification, as a means in smoke abatement, is accepted.

114.03 **The Factors in the Problem:** Before attempting an analysis of numerical values, it will be of interest to consider briefly the nature of the more important factors entering into the problem. These are three in number, and may be defined briefly, as follows:

1. The smoke discharges from the steam locomotive constitute a definite source of atmospheric pollution. The fundamental factor is that of determining the percentage of the total smoke of Chicago which is contributed by the steam locomotive.

2. The electric operation of Chicago's railroad terminals must depend upon the existence and operation of steam driven electric generating stations. Such stations must burn coal, and this will give rise to smoke. The complete elimination of the steam locomotive, therefore, while serving to free the atmosphere of Chicago from all locomotive smoke, must lead to the introduction of new sources of smoke in the form of power stations. The benefits in smoke abatement lie in the difference between the amount of smoke made by steam locomotives and that which will be made by the electric power stations.

3. Smoke is not the only polluting constituent of Chicago's atmosphere. Since atmospheric dirt arises from other sources, a given reduction in the amount of smoke will not produce an equal reduction in the amount of atmospheric dirt. If all the smoke of Chicago were eliminated, there would still be dirt in Chicago's atmosphere.

With this understanding of the general problem, it will be of interest to note the quantitative measures of the several effects considered as set forth by the investigations of the Committee.

114.04 Steam Locomotives and Atmospheric Pollution: The contributions of the steam locomotive to the pollution of Chicago's atmosphere have already been set forth (chapter 106). Pollution appears in the form of visible smoke, in the form of the solid constituents of smoke which include soot, dust and particles of fuel and ash, and in the form of gaseous products of combustion. The contributions to atmospheric pollution of all steam locomotives in Chicago, in their relation to the contributions of all other fuel consuming services, are briefly set forth by table CXXXII.

TABLE CXXXII. PERCENTAGE OF THE TOTAL SMOKE OF CHICAGO WHICH IS PRODUCED BY STEAM LOCOMOTIVES AND BY ALL OTHER SERVICES COMBINED

Form	Service		
	Steam Locomotives	All Excepting Steam Locomotives	All
Visible smoke	22.06	77.94	100.00
Solid constituents of smoke	7.47	92.53	100.00
Gaseous products of combustion	10.31	89.69	100.00

114.05 Electric Operation of the Railroad Terminals of Chicago and Atmospheric Pollution: The operation of steam locomotives within the city of Chicago during the year 1912 involved the use of 2,099,044 tons of coal. From data elsewhere presented (chapter 211) it can be shown that the introduction of electric operation, to the extent necessary to permit the removal of all steam locomotives from the territory within the city limits, would involve the consumption, in electric power generating stations, of 807,762 tons of coal.[*]

The high pressure steam boiler service now consumes 7,316,257 tons of coal a year (chapter 104). The increase in the consumption of this service due to complete electrification would therefore be:

$$\frac{807,762}{7,316,257} \times 100 = 11.04 \text{ per cent}$$

The contributions of the high pressure steam boiler service to the pollution of the atmosphere, on the basis of present fuel consumption, have already been set forth (chapter 108), as follows:

Visible smoke	44.49 per cent of the total from all sources.
Solid constituents of smoke	19.34 per cent of the total from all sources.
Gaseous constituents of smoke	44.96 per cent of the total from all sources.

If it could be assumed that the new power station required for the electric operation of Chicago's railroad terminals would discharge smoke possessing all the characteristics of the smoke discharged by the average high pressure steam boiler plant, the effect of electrification would be to increase the amount of smoke discharged by the high pressure steam boiler service by 11.04 per cent.

Such an assumption, however, is not entirely justified. It is reasonable to assume that a large electric power station erected for the operation of the Chicago railroad terminals would conform to high standards of construction and would give a better performance in operation than that of the average of all existing high pressure steam power plants. This assumption justifies the following procedure.

The visible smoke discharged by the high pressure steam boiler service of Chicago has an average density of 10.42 per cent. But the records of the Committee show, also, that the average density of visible smoke emitted from the stacks of an existing electric power station in Chicago is only 4.26 per cent, and it is believed that the operation of a new plant, erected for the

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[*] Coal consumption for electric power is obtained as follows:

Estimated energy required at the power station switchboard each 24 hours, 11,000-volt a. c. system, 1,765.200 kilowatt-hours.

Estimated coal consumption, 2.5 pounds per kilowatt-hour at switchboard.

Therefore,

$$\frac{2.5 \times 1,765.200}{2,000} = 2,207 \text{ tons per day}$$

Coal consumption for electric power for 1912, 2,207 x 366 = 807,762 tons; that is, this quantity of fuel must be added to the total now burned in all services except the locomotive service to sustain the electric operation of the railroads.

purposes of electrification, would be attended by the emission of visible smoke of not more than 4 per cent density. Upon this basis the increase in visible smoke, due to an increase of 11.04 per cent in the amount of coal burned under high pressure steam boilers, would be:

$$\frac{.1104 \times .04}{.1042} = 4.24 \text{ per cent}$$

It is not possible to segregate, from the records of the Committee, the performance of any large electric power station with reference to the solid and gaseous constituents of smoke, and an examination of the results of tests made on many types of high pressure steam boilers does not indicate any law by which these elements of the smoke of the new plant can be derived. Progress in power plant design has, on the whole, led to the use of higher rates of combustion and probably to some increase in the solid constituents of smoke. In the absence of a more exact basis, it has been assumed that a new plant will give the results of the average of all the plants of this class tested by the Committee. On this basis, the increase in the solid constituents of smoke and in the gaseous products of combustion from high pressure steam boilers will be the same as the increase in the coal burned, or 11.04 per cent.

From the foregoing it will be seen that the increase in the output of smoke from the high pressure steam boiler service, which will result from the establishment of a new plant for the purposes of electrification, will be as follows:

	PER CENT
Visible smoke	44.49 x 0.0424 = 1.89
Solid constituents of smoke	19.34 x 0.1104 = 2.14
Gaseous products of combustion	44.96 x 0.1104 = 4.96

The contribution of the high pressure steam boiler service, under conditions which will be introduced by the complete electrification of Chicago's railroad terminals, in terms of the total smoke of Chicago, will be:

	PER CENT
Visible smoke	44.49 + 1.89 = 46.38
Solid constituents of smoke	19.34 + 2.14 = 21.48
Gaseous products of combustion	44.96 + 4.96 = 49.92

114.06 Net Reduction, as a Result of Complete Electrification, in the Smoke Discharged into the Atmosphere of Chicago: The net reduction in the amount of smoke discharged into the atmosphere of Chicago which will result from the complete electrification of the railroad terminals is as follows:

		PER CENT
Visible Smoke:		
Reduction through the elimination of the steam locomotive, per cent of total	22.06	
Increase arising from new electric power plant loads, per cent of total	1.89	
Net reduction in the total visible smoke of Chicago		20.17
Solid Constituents of Smoke:		
Reduction through the elimination of the steam locomotive, per cent of total	7.47	
Increase arising from new electric power plant loads, per cent of total	2.14	
Net reduction in the total solid constituents of smoke of Chicago		5.33
Gaseous Products of Combustion:		
Reduction through the elimination of the steam locomotive, per cent of total	10.31	
Increase arising from new electric power plant loads, per cent of total	4.96	
Net reduction in the total volume of the gaseous products of combustion of Chicago		5.35

114.07 The Possibility of Reducing Smoke through Improvements in Locomotive Service: The preceding section shows what would be accomplished in the purification of Chicago's atmosphere by modifying the fuel consuming industries of the city, as they existed in 1912, through the electrification of the railroads.

An exhibit of the results which may be expected to accrue from electrification, as set forth in the preceding section, naturally suggests an inquiry as to what might be accomplished, in the absence of electrification, through improvements in locomotive practice. While a quantitative answer to this question cannot be given, it is evident that substantial progress in recent years has been made in reducing the smoke emitted from steam locomotives in Chicago. There is every reason to believe also that the process has not yet reached its maximum development. The improvement to be noted has resulted both from embellishments in locomotive design and from the exercise of greater skill in locomotive operation.

Among the more important changes in locomotive design which have aided in smoke abatement are to be included the enlargement of grates, which has resulted in lower rates of combustion per unit area of grate and consequently in a reduction in the amount of solids in locomotive smoke; the adoption of the brick arch in locomotive fire-boxes, by means of which a reduction in the amount both of visible smoke and of the solid constituents of smoke has been effected.

the more efficient design of draft appliances, by which the air currents stimulating the fire have been modified and smoke production diminished; the introduction of superheaters, whereby the efficiency of the locomotive as a whole has been increased, the amount of fuel required for the performance of a given service decreased and the volume of smoke diminished; and the introduction of steam jets and other appliances especially designed to abate visible smoke.

Meanwhile, the amount of smoke emitted within the city has been greatly reduced through the exercise of diligence and skill in the operation of locomotives. The importance accorded this aspect of the matter by the railroads of Chicago is to be seen in the number of smoke inspectors they have employed. The records of the Committee show that there is a substantial difference in the quantity of smoke discharged by locomotives outside of the city limits, where there is no inspection, as compared with the amount discharged by locomotives within the city, where the operation is subject to inspection.

When, therefore, the fact is set forth that electrification will serve to reduce the amount of visible smoke entering the atmosphere of Chicago by 20 per cent, it should not be forgotten that progress in locomotive design and practice, without electrification, has operated and will continue to operate to bring about a reduction which, if smaller than that to be effected through electrification, is nevertheless material; and when emphasis is given the fact that electrification will serve to reduce the amount of the solid constituents of smoke and the gaseous products of combustion entering the atmosphere of Chicago by about 5 per cent, it should not be forgotten that progress in locomotive design and operation can very likely be depended upon to bring about an equal reduction.

114.08 Effect of Complete Electrification on the Dust Content of Chicago's Atmosphere: The preceding comparisons show the effects which will be produced, by the substitution of a system of complete electrification for the present steam locomotive, upon such portions of the atmospheric pollution as arise from smoke. It has already been shown (chapter 112) that, of all the dust and dirt in the atmosphere of Chicago, not more than two-thirds is of fuel origin. Since, therefore, there is more dirt in the atmosphere than is supplied by smoke discharges, a given percentage of reduction in the dust of smoke will afford a smaller reduction in the total dust of the atmosphere. That is, while electrification will effect a reduction of 5.33 per cent in the amount of the solid constituents of smoke discharged into the atmosphere, the reduction in the amount of atmospheric dust and dirt will be only about two-thirds of this, or less than 4 per cent.

114.09 Conclusions Relating to the Results which may be Expected from Complete Electrification as a Means in Smoke Abatement: By combining facts already set forth and omitting decimals in expressing numerical values, it will be seen that the net effects of the elimination of the steam locomotive from the railroad terminals of Chicago, and of the substitution of a system of electrification to an extent shown to be necessary under these conditions, may be summarized as follows:

1. The amount of visible smoke discharged into the atmosphere of Chicago will be reduced by not more than 20 per cent.
2. The amount of solid constituents of smoke (soot, ash and fuel particles) discharged into the atmosphere of Chicago will be reduced by not more than 5 per cent.
3. The amount of dust and dirt arising from all sources, in the atmosphere of Chicago, will be reduced by not more than 4 per cent.
4. The volume of gaseous products of combustion discharged into the atmosphere of Chicago will be reduced by not more than 5 per cent.

It is upon the basis of these facts that the merit of any proposal involving complete electrification as a means in smoke abatement must be considered.

115. CHICAGO'S PROBLEM IN SMOKE ABATEMENT AS DISCLOSED BY THE RESEARCHES OF THE COMMITTEE

SYNOPSIS: Whatever final disposition may be made of the proposal to electrify the railroad terminals of Chicago, the city will continue to have its problem of smoke abatement. The problem is one of constantly increasing importance; it is a function of the industrial growth of the city. While the Committee's investigations have not been conducted primarily for the purpose of establishing or recommending a municipal procedure in smoke abatement, certain facts have been developed which are of interest in this connection. These facts are reviewed and their significance discussed in this chapter.

115.01 The Problem: The history and the present day aspect of smoke abatement as a municipal problem have been duly set forth;* the literature of the subject has been abstracted; the effects of smoke have been discussed; and the various steps, legal and administrative, which have been taken by the city of Chicago in its efforts to reduce the amount of smoke discharged into its atmosphere, have been reviewed.† To facts thus disclosed there may now be added those which have been developed by the researches of the Committee.‡ While these researches have not been conducted for the purpose of developing methods in smoke abatement, they have yielded results which supply a good definition of Chicago's problem. With these in hand, what is to be the character of Chicago's next step? The answer to this question is by no means simple, but there are certain fundamental facts to be recognized, the more important of which may be briefly considered.

115.02 Significant Factors in the Problem: Among the factors in the problem, the significance of which has not commonly been recognized, are four which are worthy of especial emphasis in this connection. The first concerns the number and diverse character of the sources of smoke. It can no longer be urged that this or that particular interest produces the smoke of Chicago; all interests contribute to it. The business man can no longer attach especial blame to the apartment house owner, nor the apartment house owner to the railroad, nor the railroad to the manufacturer, for all are joint contributors to the sum total of Chicago's smoke. As joint contributors, they are jointly responsible for the resulting atmospheric pollution. The problem of smoke abatement, as disclosed by the investigations of the Committee, cannot be effectually dealt with by giving attention to a single segregated interest; it is one in which every interest must be given attention. It is the problem of the whole city.

A second significant fact disclosed by the researches of the Committee is that which emphasizes the relatively great importance of the solid constituents of smoke. Hitherto most discussions concerning smoke, and practically all measures designed to show the extent of atmospheric pollution resulting from it, have dealt only with its cloud effects. It now appears that the cloud effects produced by smoke are of secondary importance as compared with effects produced by the soot and dust of smoke. The problem of smoke abatement, therefore, as viewed in the light of the Committee's disclosure, is not entirely or largely a problem of suppressing visible smoke but is one of suppressing the shower of dust and cinders constantly falling from a smoke polluted atmosphere.

The significance of the solids in smoke, as agencies in atmospheric pollution, suggests the third important fact disclosed by the Committee's researches, namely, that atmospheric pollution is not entirely the result of soot and dust in their initial descent to the exposed surfaces of the city, but that such material is subject to secondary flights which persist until some exceptional cleansing process eventually eliminates them. Moreover, the sum total of atmospheric dirt includes, with the solids of combustion, considerable

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* Chapter 101.
† Chapter 102.
‡ Chapters 103 to 113 inclusive.

amounts of dust arising from many activities incident to the life of the city. The problem, therefore, of reducing to a minimum the sum total of atmospheric dirt is not enitrely a problem in smoke abatement but, to a considerable extent, a problem concerning municipal cleanliness. The process, therefore, of reducing to a minimum the atmospheric pollution of the city must deal with visible smoke, with the solid constituents of smoke and with every source from which these arise; it must also deal with all accumulations of dirt in a manner which will promote the cleanliness of the city.

The fourth significant fact is to be found in the obvious tendency of all sources of atmospheric pollution to increase. The fuel consuming industries of the city are expanding; the traffic of the city streets is increasing and the amount of merchandise handled in and out of the city is growing year by year. Improvements in the methods of burning fuel, or of city cleaning, imply an improvement in atmospheric conditions only in a relative sense. The elimination of an entire fuel consuming service would reduce the amount of pollution entering the atmosphere at the time of its accomplishment, but would constitute no guarantee that the sum total of atmospheric pollution might not increase subsequently to even greater amounts. Improvement in service may, therefore, only result in checking an undesirable growth. This fact emphasizes the importance of giving attention to every means which can be relied upon to reduce the production of polluting agencies at their source.

The relative standing of the several fuel consuming services as herein set forth is based upon conditions as they existed in 1912. It is probable that the ratios as determined for that year will hold for many years to come, unless individual services are to be affected by new controlling influences which may be hereafter introduced.

115.03 Progress in Smoke Abatement — A Matter of Development: A revolution in practice which will result in the elimination of existing sources of atmospheric pollution is not to be expected; first, because present day knowledge is insufficient to supply the necessary means; and second, because the immediate application to all sources of pollution, even of such means as are now available, is mechanically and financially impracticable. However urgent the need, progress in satisfying it must be gradual; it must be evolutionary. Chicago is not peculiar among the cities of the world in the possession of this problem. Every great center of population is confronted with it. Its intrusion is part of the price which is paid for the privilege of maintaining the activities and the concentration of population which characterize the modern city.

The problem of smoke abatement in Chicago is difficult, because among the conditions which have been effective in stimulating the growth of the city there must be included the proximity of the city to an abundant supply of fuel. Few of the world's great cities are within such easy reach of so extensive a deposit of coal. The Illinois-Indiana coal fields, covering an area of many thousands of square miles, extend almost to Chicago's threshold. This coal is Chicago's coal and she must use it. While, for the present, Chicago draws heavily on more distant fields, she must ultimately satisfy her needs from her local supply.

All coal is complex in chemical composition and in structure. Differences in these characteristics affect its behavior on the grate. Illinois coals as compared with eastern coals are high in volatile matter. Furnaces which are satisfactory for coals low in volatile matter give off excessive amounts of smoke when Illinois coals are burned. Chicago's problem in smoke abatement, therefore, is complicated by the fact that the coals she must use are those commonly referred to as smoky coals. People are coming to understand, however, that it is not sufficient to commend one coal as smokeless and to condemn another as smoky; that whether a coal is smoky or otherwise, is dependent upon the extent to which the conditions governing its consumption are suited to its needs; that furnace design and construction must respond to the peculiar requirements of the fuel to be burned; and that when this is done no coal need be discarded because it is smoky. Chicago's great resource is a conveniently located commercial fuel, and the difficulties to be met in utilizing this resource constitute merely an incidental scientific problem.

The problem of smoke abatement in Chicago is difficult also because the amount of coal consumed is large. Each step in the process by which the city has attained its present state has enlarged its fuel burning capacity. For example, its buildings have been extended to an unusual height, and the space in them and the activities for which this space provides have created unprecedented demands for heat and power. The number of such buildings has introduced a great fuel consuming industry in an area where the population is most congested. The height of buildings requires the use of lofty chimneys or stacks, which permit coal to be burned at rates not before common under stationary boilers. High rates of combustion imply high percentages of fuel dust in smoke. The smoke discharged into the atmosphere from such stacks far above the city streets is distributed over wide areas. The concentration of activities made possible by the presence of lofty buildings has stimulated traffic in the streets and on railroads tributary thereto. The constant coming and going of the multitudes has created heavy demands for power and transportation, which are met through the consumption of fuel. In all of its various classes of service Chicago burns each year approximately 8 tons of coal per capita, while Cleveland burns but 5, Glasgow, Manchester and Leeds but 4 each, Hamburg but 3, and Berlin and Paris less than 2 tons each. Wherever fuel is burned certain effects appear. These may take the form of visible smoke or of tar or dust emissions, and they must always appear in the form of gaseous products of combustion. As a consequence, objections to smoke are valid only in so far as they may be based upon conditions which are avoidable, and ill-advised restrictions against the use of fuel are not only unreasonable, but harmful to the larger and better interests of the community. It is for this reason that the problem of smoke abatement cannot be solved by any simple campaign for the enforcement of restrictions. It is a question which, in all its aspects, is of the highest importance to the welfare of the city. It is a scientific question. It cannot safely be answered until many local conditions have been studied and defined. It is a living question, since it assumes new aspects as the state of the art develops.

115.04 The Importance of a Broad View: In any effort to improve a given practice, it is important to secure a clear understanding of the relative values of the factors involved. This accomplished, the first steps in the work of betterment may well be directed toward those factors which possess the highest values. The several classes of service and their relative importance as producers of smoke have been set forth in a previous chapter (chapter 105) as follows:

	VISIBLE SMOKE PER CENT	SOLID CONSTITUENTS (SOOT AND DUST) PER CENT
High pressure steam stationary power and heating plants	45	19
Furnaces for metallurgical, manufacturing and allied processes . . .	29	64
Steam locomotives	22	8
Low pressure steam and other stationary heating plants	4	9
Total	100	100

This statement emphasizes the importance of the high pressure steam stationary power and heating plants as producers of smoke. Not only is this the largest service but its output of smoke and dust is more than double that of the steam locomotives of Chicago. Any measure which is effective in its application to this service will produce greater results in clarifying the atmosphere than will equally effective measures applied to less important services. With this understanding of the general problem, it will be of interest to consider, in connection with each service, the possibilities of progress in smoke abatement as judged by established practice and as may be suggested by recent scientific developments.

115.05 High Pressure Steam Stationary Power and Heating Plants: It has been estimated by the Committee that within the city of Chicago there are approximately 17,000 high pressure steam boilers, served by not less than 11,000 smoke-stacks. In a census of steam boilers made by the Committee, a map was prepared upon which the location of each boiler plant was indicated. A small section of this map is presented as fig. 92.

Many of Chicago's large business buildings have steam power plants of large capacity which supply energy for elevator service, for lighting, for power and water service, and for various minor purposes. In the loop district there are from four to eight power plant stacks in each block. Some of the downtown buildings are, in fact,

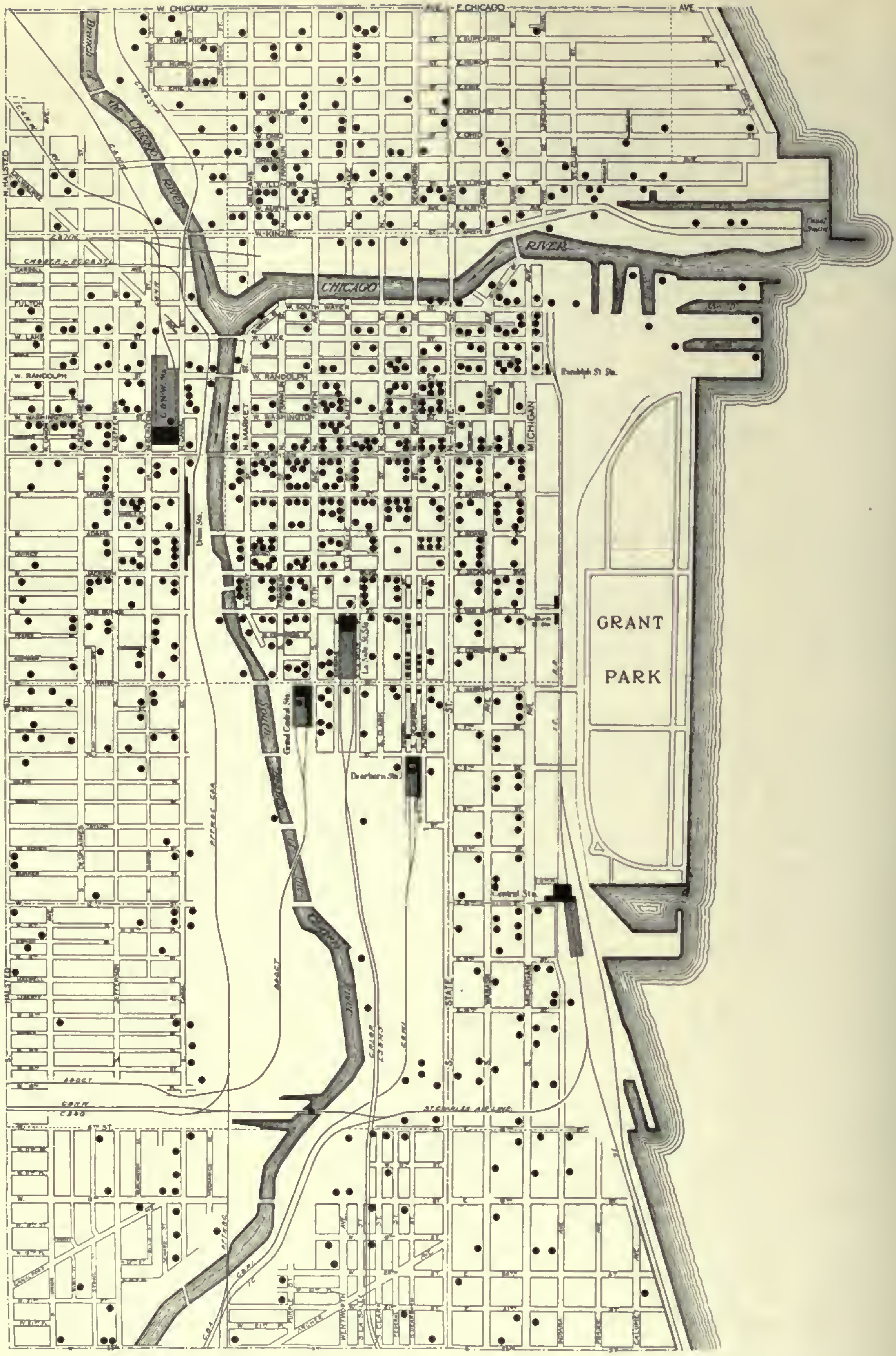

FIG. 92. SECTION OF MAP SHOWING LOCATIONS OF STEAM BOILER PLANTS IN CHICAGO

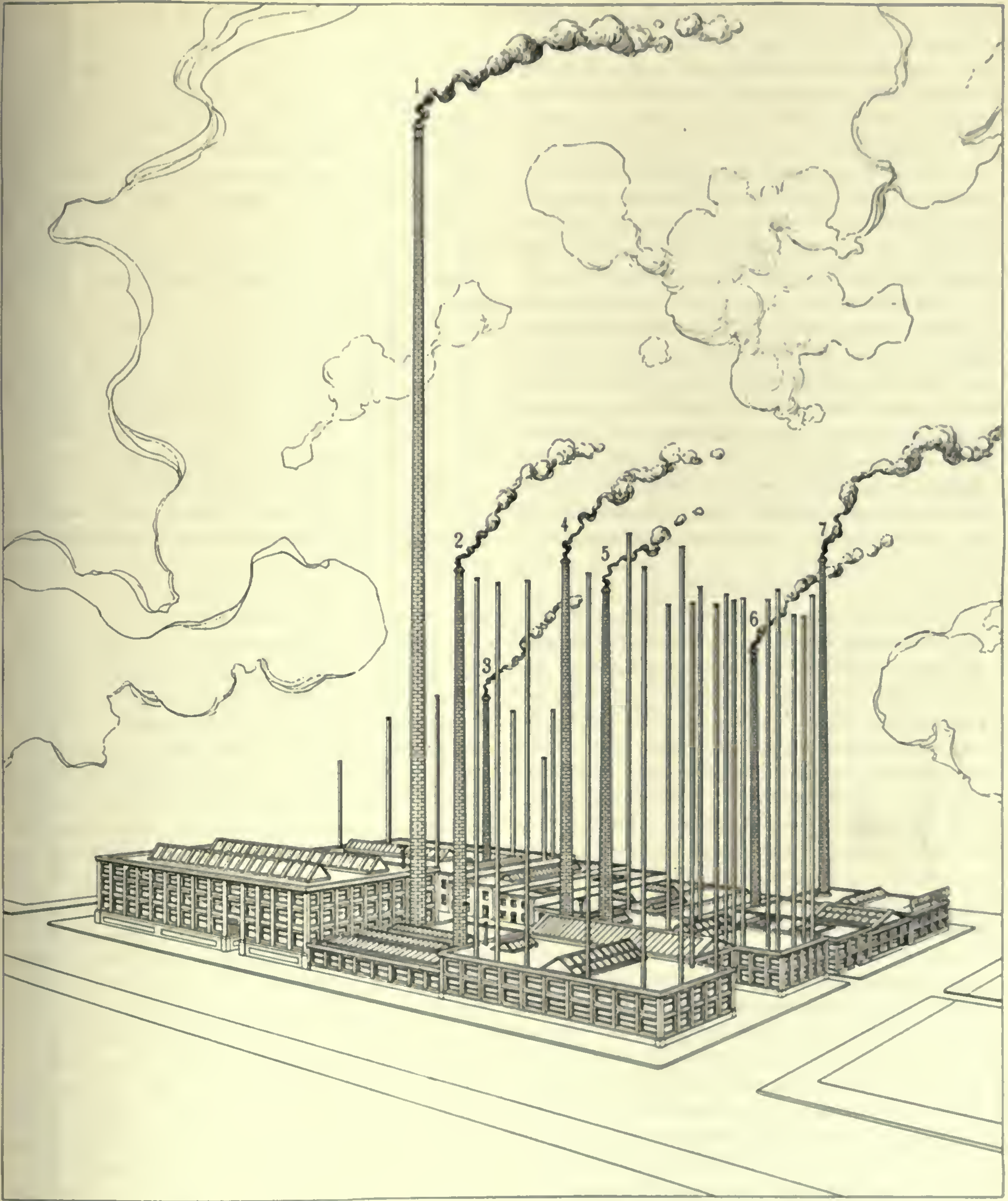

FIG. 93. A TYPICAL BLOCK IN THE BUSINESS DISTRICT OF CHICAGO IN WHICH THE ACTUAL BUILDINGS ARE ASSUMED TO GIVE WAY TO BUILDINGS OF FACTORY HEIGHT AND IN WHICH THE EXISTING SMOKE-STACKS AND CHIMNEYS ARE ASSUMED TO REMAIN AT THEIR PRESENT HEIGHT. THE DRAWING IS AN ISOMETRIC PROJECTION. THE NUMBERS INDICATE POWER PLANT STACKS

power plants extended upward to give floors which may be occupied for business purposes. It follows that those who occupy these buildings conduct their activities in a power plant district and are subject to the inconveniences incident to such an environment.

A drawing, showing a typical block in the business district of Chicago, in which the buildings have been cut down to factory height and existing smoke-stacks and chimneys are shown at their present heights, is presented as fig. 93.

If all the smoke from furnaces serving high pressure boilers could be eliminated, the pollution of Chicago's atmosphere would not only be reduced by approximately one-half as measured by its cloud effect and by one-fifth as measured by the presence of polluting dust and soot, but relief would be given at points where the pollution affects the greatest possible number of people. What promise is offered by the present state of the art that such a result may be secured?

Visible Smoke

Great progress has been made during the last few years in the development of furnaces designed to give so-called smokeless combustion. The characteristics of these furnaces are set forth with some detail in chapter 101. For the present purpose, it is necessary only to note that all such furnaces, as applied to steam boilers, are smokeless only in the sense that they effect a reduction in the amount of visible smoke emitted. Without the automatic stoker and the various other devices for reducing smoke now in service in the large boiler plants of Chicago, the cloud effects from boiler fires would be far heavier than at present.

A first step, therefore, in further reducing the smoke of furnaces serving high pressure steam boilers involves the more extended use of those types of furnaces which have already proved their value in service. Through their automatic action, such furnaces contribute to economy in operation when applied to large plants. Their use in connection with small plants, however, generally involves increased costs, the one return for which is to be found in a reduction in the amount of smoke produced. For this reason, progress in extending the use of such apparatus to small plants has been slow.

Solid Constituents of Smoke

The various types of smokeless furnaces do not in themselves bring about a reduction in the discharge of solid matter from the stack. Methods in common use today do not normally provide for its suppression. There are, however, four possible lines of procedure by which this may be accomplished. Each of these possesses elements of promise; each presents distinct though different limitations, although some are at present in the experimental stage of development. These lines of procedure are:

1. Smoke washing.
2. Smoke entrainment through electric grills.
3. The substitution of electric energy, derived from a remote source, for local steam developed energy.
4. The elimination of solid fuel and the substitution therefor of manufactured gas.

It will be of interest to consider the possibilities of progress in the general adoption of each of these possible procedures.

Smoke Washing

In this process the smoke, in its passage from the furnace to the base of the stack, is made to pass under an inclined apron, the lower edge of which approaches a water surface. A film of water runs down over the apron and passes in a shower from its lower edge to a receptacle below. The whole arrangement is such that the products of combustion striking the inclined apron are projected downward toward the surface of the water and, in passing under the edge of the apron, they meet the descending shower of water. Many of the coarser particles are projected into the water before the shower is reached, and those that remain are carried downward by the shower. Once in contact with water, the course of these particles is stayed. The resistance offered the products of combustion in passing under the apron and through the shower, and the cooling effect upon the gaseous products, tend to suppress the draft action which would otherwise be stimulated by the chimney, and losses thus sustained are made good by mechanical means. An induction or exhaust fan is therefore a necessary part of any smoke washing device. Considerable space is required for the installation of smoke washing machinery. It is generally assumed that this space should be supplied at the base of the stack. In many cases the physical difficulties to be encountered in finding room for the introduction of the new devices in existing plants would be great. The possibility of installing smoke washing machinery upon the roofs of buildings is admitted, but such a location introduces difficulties in matters of detail which are regarded as serious.

Smoke washing as a process for general application is still in an experimental stage. Enough has been accomplished to prove that by means of it practically all the objectionable elements in smoke can be suppressed. The discharge from a washery is not without cloud effects, but the clouds are due chiefly to the presence of water vapor and quickly become dissipated.

Among the difficulties to be overcome in applying the process are those arising from acid effects. The mingling of the products of combustion with water converts the sulphur compounds present in smoke into sulphuric acid, and the problem of maintaining metallic parts employed in the construction of smoke washing machinery is one which, in early experiments, gave serious trouble. The corrosive effects are not only manifested in the machinery itself, but in all the conduits through which the "washed smoke" is discharged. Obviously, any resort to smoke washing will require the greatest care in the selection of materials to be used, as well as the exercise of great skill in the design of flue connections and stacks.

The amount of solid material precipitated into the water is sufficient to make the matter of its separation and removal one of considerable consequence. If the operation of a plant can be intermittent, the solids will settle and may, from time to time, be removed from the bottom of the tank in which they are collected. If the operation of the plant must be continuous, some process by which the water is continuously circulated through suitable filters will probably prove advantageous. These are all matters now regarded as being in process of development.

A modified smoke washing device, which has been referred to as a "cinder catcher," has been placed in operation by the New York Edison Company. It has been applied to existing plants between the boiler and the stack. The device is such that the inclined apron, which serves to deflect the gases downward into water, is hinged in such manner that the distance between its lower edge and the surface of the water may be varied to suit the requirements of changes in rates of power at which the boiler is operated. The proportions of the device are such that the gases are neither throttled nor cooled to an extent requiring the use of mechanical means for stimulating draft, though the effect of the device upon the draft action reduces somewhat the capacity of the boilers. "Comparative tests have shown that, whereas an unequipped stack discharges cinders amounting to from one to two per cent of the weight of coal fired, in case of another similar stack, equipped with a cinder catcher, about 95 per cent of the cinders and ash were removed."[*] Experiments leading up to the present practice have been in progress since 1906. Trouble has been experienced from the corrosion of the apron and pan. The vaporization of water in the pan under the apron also has been such as to introduce a new item of expense. More than a hundred boilers are equipped with this device.

In view of the preceding statements, it is of interest to note that one of the first smoke washing plants to be installed in this country was that of the Chicago & North Western Railway, which was placed in operation in Chicago in 1909 at Chicago Avenue to handle the smoke from a locomotive roundhouse. Another installation of significance is that of the New York Central lines at the company's Englewood Yard in Chicago. It was placed in operation in 1913 in connection with a large roundhouse.

The financial aspect of smoke washing, as applied to the high pressure steam stationary power and heating plants of Chicago, must cover the value of the space occupied by the necessary machinery, the first cost of the apparatus, interest, maintenance and depreciation costs and operating expenses. Included in the operating expenses is the cost of the power necessary to operate the fan, the cost of water and the cost of separating the precipitate from the water and disposing of it.

Mr. Willis H. Carrier,[†] who has given careful attention to the problem of smoke washing, has

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[*] "The Central Station in Its Relation to the Problem of City Dust," a paper by Messrs. Bolton, Grady and Deghuee, Convention of the Association of Edison Illuminating Companies, September, 1914. See also Electrical World, p 602, September 26, 1914.

[†] Chief Engineer, Buffalo Forge Co., Vice-President and Consulting Engineer, Carrier Air Conditioning Co., Buffalo, N. Y.

submitted the following notes for the benefit of the Committee:

> "1. I do not believe that it is practicable to build the washing chamber of anything except concrete or brick.
>
> "2. This chamber would preferably be arranged vertically in the form of a tower with the double pass for the gases. Considerable water will have to be used, as it is necessary to cool the gases thoroughly before effective washing can be accomplished.
>
> "3. The induced draft fan will have to be placed between the boilers and the washer, discharging into the washer as into the stack.
>
> "4. The height of the washer tower will vary somewhat with the capacity, but will be about 40 feet high to the stack proper."

Mr. Carrier estimates the cost of a smoke washing installation for a 1,000-horse-power boiler plant, which would be capable of handling the smoke from 5,000 to 6,000 tons of coal per year, at $3,500 to $4,000, if made in connection with the erection of new plants. The installation costs, if made in connection with existing plants, "will be considerably more than for new."

The cost of operating and maintaining such a plant, including the cost of water at $0.025 per 1,000 gallons and of power at $20.00 per horse-power per annum, and including also interest on the investment, is estimated by Mr. Carrier to be $0.30 per ton of coal burned. This estimate probably does not include any allowance for the value of the space occupied by the equipment nor for additional attendants.

Assuming that it is possible to apply smoke washing equipment to all classes of service, Mr. Carrier estimates the cost of operation and of maintenance as follows:

	PER TON OF COAL BURNED
1. Power plants (5,000 horse-power) having a coal burning capacity of 40,000 tons a year . .	$0.29
2. Power plants (1,000 horse-power) having a coal burning capacity of 8,000 tons a year . .	$0.30
3. Power plants (100 horse-power) having a coal burning capacity of 1,000 tons a year . .	$0.40
4. Domestic and heating fires having a coal burning capacity of 500 tons a year	$0.70
5. Domestic and heating fires having a coal burning capacity of 100 tons a year	$1.00

While the uncertain character of such estimates must be recognized, the development of the practice being as yet insufficient to provide a substantial basis for them, they suggest the possibility of completely eliminating all smoke which now arises from Chicago's greatest smoke producing service.

Smoke Entrainment through Electrical Means

The precipitation of suspended matter in gases may be accelerated by electrical means. If the products of combustion are made to traverse an electrostatic field, the solid particles may be intercepted. This principle has been employed in the removal of solids from the gases of metallurgical and other industrial furnaces. A few applications have been made in connection with the furnaces of boiler plants.

The principle involved has been in the process of development for many years and various scientists have been interested in it. Sir Oliver Lodge, of the University of Birmingham, England, has employed the principle in eliminating the solids in smoke. In this country Dr. F. G. Cottrell, while occupying the position of instructor in chemistry at the University of California, repeated the experiments of Sir Oliver Lodge and sought to supplement the pioneer work by a choice of equipment which would respond to the needs of modern engineering practice.

From activities originating in this experimental work, a group of patents has recently been presented as an endowment to the Smithsonian Institution at Washington.* Out of this action has grown a "Research Corporation," an organization which has been brought into existence to administer the technical and business development of these patents and others which may in the future be presented in a similar way to the various institutions of learning, and to return to these institutions for use in scientific research the entire profits arising from such business.†

In the practical development of the principle of electrical separation, laboratory experiments were followed by an installation at the Hercules Works of the E. I. DuPont-DeNemours Powder Company at Pinole, on San Francisco Bay, where particles of acid, which would otherwise have passed off in the fumes from a contact sulphuric acid unit, were successfully precipitated and intercepted.

These experiments at Pinole have been followed by a series of installations in connection with smelters and cement mills, the purpose of which has been to entrain and recover the mineral

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* Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1912, pages 3 to 6.

† "The Research Corporation, an Experiment in Public Administration of Patent Rights," by F. G. Cottrell. Report of the Eighth International Congress of Applied Chemistry, September, 1912. Reprinted in the Journal of Industrial and Engineering Chemistry, December, 1912.

dusts which would otherwise have created a nuisance or involved a loss in materials treated.

Walter A. Schmidt refers to the principles of the action, and gives a description of an installation by the Riverside Portland Cement Company,* as follows:

"It might be well here to say a few words regarding the underlying principle of the Cottrell Electrical Precipitation Processes, for those who are not acquainted with the processes or who have not the time to read the reference cited. Stated in a few words, the principle consists of bringing the dust laden gases under the influence of a series of electrodes, some of which maintain a 'silent' or 'glow' discharge. By virtue of the discharge, the space between the electrodes becomes filled with gaseous ions and the dust particles passing through this space become charged by having these ions impinge upon them, imparting their ionic charges to the particles. The charged particles are then passed through an intense electric field which causes them to migrate in the direction of the field, which, in the commercial apparatus, is arranged transverse to the direction of the flow of the gases. The dust particles are by this action drawn out of the gases and deposited upon the electrodes, the gases being permitted to go their way unaffected and emerge from the treating apparatus freed from the solid particles which had been held in suspension.

"The distinct advantage which this process has over the mechanical processes arises from the fact that the gases themselves play no part in the action in the treater, except as carriers of electricity. In all mechanical processes, the entire volume of gases must be acted upon in such a way as to take advantage of the differences in specific gravity between the suspended particles and the gases themselves, or some similar action. In the electrical processes, the gases are permitted to pass through the apparatus unaffected, while the particles themselves are taken hold of individually by the electrical field and acted upon in such a manner as to draw them out of the current of advancing gases and so as to precipitate them upon the collecting electrodes. In order to maintain a definite direction of migration of the dust particles, the electrodes must be given an unidirectional electrostatic charge, which in the commercial apparatus is generated by rectifying a high tension alternating current. In the commercial apparatus the potential varies under different conditions from 20,000 to 40,000 volts.

"The electrode system consists of two forms of electrodes: first, the discharge electrodes, which are made in various forms, depending upon conditions, but are always of a light construction and are so chosen as to maintain a heavy electrical discharge from them; secondly, the collecting electrodes upon which the solids are precipitated. These are usually of a heavy construction and the form and arrangement is so chosen that no discharge takes place from their surface. The two forms of electrodes are alternated across the apparatus with an electrode spacing of from two to six inches, this distance varying with the conditions to be met. A series of these rows of electrodes is placed in the treater so that the dust particles are brought under the successive action of this series of electrodes. The length of the treater is so chosen as to effect the desired cleaning of the gases. The cross-section of the apparatus is made such as to bring a balance between the two forces acting upon the suspended particles, namely, the frictional force tending to carry the solid particles along with the gases, and the electrical force tending to draw the suspended particles out of the advancing current of gases.

"In the installation at the Riverside Portland Cement Company, the treater has a cross-section of 12 by 16 feet and an over-all length of 20 feet. . . . The apparatus is placed upon a platform constructed at a height corresponding to the top of the original stacks, namely, 80 feet above ground. Upon this platform is placed a short stack extension which extends through the roof of the building structure and is supplied with a damper of special design. Upon either side of the stack is placed a complete electrical treater separated from the stack extension by a large louvre damper. By means of these three dampers the gases can either be conducted through one or the other or both treating chambers or emitted directly into the atmosphere as occasion may warrant. Each stack is equipped with two treaters so as to have an auxiliary apparatus for each kiln. In case one treater should be shut down for repairs, cleaning or the like, the other treater will be able to take care of the gases with moderate efficiency. Under normal conditions the gases will be permitted to pass through both treaters, insuring a thorough cleaning of the gases. The electrode spacing is here chosen at 6 inches and there are 20 rows of discharge electrodes in series. The dust is precipitated upon the collecting electrodes, which are cleaned once every three or four hours by being given a mechanical rapping, this action being made automatic in so far that the operator merely puts an electric motor into operation. The dust falls into hoppers from which it is again conducted into the bins feeding the rotary kilns. Each treater is supplied with a small outlet stack 20 feet high, which is sufficient to compensate for the resistance offered to the gases by the treater. . . . Sensitive pyrometers do not indicate any change of temperature in the kilns

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* "The Control of Dust in Portland Cement Manufacture by Cottrell Precipitation Process," a paper before the Eighth International Congress of Applied Chemistry. See also a paper entitled, "The Theoretical and Experimental Consideration of Electrical Precipitation," by A. F. Nesbit, and a paper entitled, "Practical Applications of Electrical Precipitation and Process of the Research Corporation," by Linn Bradley, both presented at the third midwinter Convention of the American Institute of Electrical Engineers, New York, February 19, 1915.

or stacks when the gases are permitted to escape directly into the atmosphere or are passed through the treater.

"The operating costs of the apparatus are low. A complete treater of the size described consumes approximately 7.5 kilowatts. This includes electrical energy for all motors. A 5,000-barrel mill will, therefore, consume approximately 75 kilowatts in an entire installation. The manual labor required consists of one man per shift, of the character of men ordinarily employed to run electrical mill machinery. It is, however, usually advisable to have an extra man on duty. There is no deterioration in the apparatus under steady running, and the machinery is subject to exactly the same wear as any other piece of electrical machinery."

It is to be noted that electrical means in the precipitation and entrainment of furnace waste have thus far been applied chiefly to industrial furnaces. Dr. Cottrell states that, while the process is worthy of wide application as a means of intercepting such waste and while its application as a means of intercepting those constituents of smoke which give rise to visibility and to dust may be possible, he does not advocate its use as a general means in smoke abatement until all other simpler measures have been tried. He does not indicate what are the simpler means.

It is evident that the application of electrical precipitation as a means in smoke abatement has not yet assumed the dignity of a settled practice. It does, however, present a scientific possibility; it is entirely conceivable that, through the further development of mechanisms, the principle may be applied to the discharge of all high pressure steam boiler plants in the city of Chicago, to the end that the polluting elements in the smoke now discharged from this service may be entirely intercepted.

The financial aspects of the problem of complete suppression of power plant smoke through the use of electrical means are obviously indeterminate at this time. The forms of apparatus thus far employed are bulky. Installation costs must include the value of some increase in space for the accommodation of the apparatus and of electric equipment designed to supply direct current of high voltage for the purpose of energizing the apparatus. The operating expenses must include, in addition to the interest on the investment and the cost of maintenance and depreciation, the cost of the power necessary to energize the apparatus, the cost of controlling its action and the cost of disposing of the solids collected. It is not to be expected that, through the addition of such an installation, there will be any corresponding return in furnace efficiency or in other forms of economy. The only purpose it can serve is to eliminate objectionable elements in smoke. Both first cost and operating expense must be justified from a standpoint of smoke abatement.

Smoke Suppression through the Elimination of Solid Fuel

Assuming that the elimination of solid fuel from a portion or from the whole of the city of Chicago as a means in smoke abatement were practicable, two substitutes at once suggest themselves. These are electric energy and coal gas. From a scientific point of view, irrespective of the larger questions of financial practicability, it should be possible, through the use of either or both of these agencies, to perform all service that is now performed through the immediate use of solid fuels. The costs which would be entailed by any such substitution would be dependent upon many conditions, to some of the more important of which attention may be directed. The question to be discussed concerns the practicability of the complete elimination of the 7,000,000 tons of solid fuels now burned annually under high pressure steam boilers within the city of Chicago.

High pressure steam boilers are used primarily in the development of power. Their contributions to the heating service of the city are in most cases incidental to other services. Assuming the power load on such boilers to be fairly uniform throughout the year, the addition of the heating load in winter would not disturb their load factor by the full amount of the seasonal change in the heating load. The reason for this is to be found in the fact that exhaust steam from the power load is available for heating. It is evident that any substitute for solid fuels, for the power load, should be capable of extension to cover the heating load of high pressure steam boilers as well.

The Possible Elimination of Solid Fuels through the Substitution of Electric Energy

The power requirements of the city, which are now being satisfied through the operation of steam plants in individual buildings, may readily be supplied electrically. The effects on smoke production of such a transfer would depend upon whether the great centralized electric generating station required was located within the city itself or outside of the city, and if located within the city, upon the character of the plant.

If the generating station were to be located within the city a reduction of smoke would result because,

1. The greater efficiency of the large station, compared with many small ones, would result in a decrease in the quantity of fuel consumed.
2. There are possibilities of suppressing smoke from large plants which do not appear in the operation of small plants.

If the great central electric generating station was located at a point sufficiently remote from the city, the total smoke arising from the power load, now caused by the high pressure steam boiler plants of the city, would be entirely removed.

Such a transfer of the existing steam power load of the city to an electric power load would involve the abandonment of many steam facilities throughout the city, the installation of corresponding electric facilities at points of consumption, an increase in the power capacity of generating stations and an increase in the capacity of transmission lines. Such a procedure would entail enormous costs. Whether the change of the entire power service of the city would or would not involve increased operating expenses, would depend upon the conditions under which the transfer and the subsequent conduct of the service were sustained. An analysis of these conditions has not been undertaken. Such a change, however, would not be revolutionary. Its application to individual plants is already in progress. Every such transfer, as it occurs, tends to reduce the sum total of the load carried by comparatively small steam plants and, by so doing, it becomes an aid in smoke abatement. General progress in smoke abatement will, therefore, undoubtedly profit by an extensive and continuous investigation of individual plants to the end that a transfer in the form of power may be encouraged wherever it may be justified by conditions peculiar to the plant.

The discussion thus far deals with the transfer from steam to electricity of the power loads only. If the transfer described were brought about, it would still be necessary to retain steam boilers in many existing plants and to burn fuel under them during a portion of the year for heating, unless other provisions could be made. The state of the art presents no serious technical difficulty to the supplying of heat electrically but the process is expensive both as regards capital costs and fuel consumption. It may be assumed that the capital cost incident to generating, transmitting and absorbing a given quantity of electric energy in heating an office building in the business district of Chicago, will be approximately five times that of installing steam heating apparatus in the same building; also that the operating efficiency of such a system of central station heating, when compared with the efficiency of steam plants of ordinary construction located within the building, will necessarily be low. These statements may be accepted as indicating the financial impracticability, under conditions fixed by present procedure, of any general scheme for heating Chicago by means of steam driven electric generating stations. Conditions will, however, appear from time to time under which a certain amount of heat may be supplied profitably by electrical means in individual buildings, and the time may come when electric heating of buildings will be financially practicable. The fact remains, however, that, except under special or unusual conditions, the cost of electric heating of buildings is today prohibitive.

Practicability of the Elimination of Solid Fuels through the Substitution of Fuel Gas

The possibility of eliminating the solid fuels now consumed under high pressure steam boilers, through the introduction of fuel gas supplied from a central source, is one which readily suggests itself. For Chicago such gas must be made from coal. Its cost will depend upon many factors, such as the quantity of gas which can be sold, the daily and seasonal load factors, the characteristics of the fuel from which it is produced, the process by which it is manufactured and its heating value. An attempt to develop the details of the problem as applied to Chicago, assuming that Illinois coals will be used, develops important issues which, for the present, must be regarded as speculative. The fuel requirements for boiler service are, among those of all the different fuel consuming services, the most difficult to satisfy with coal gas supplied from a central source, since all requirements of the service, excepting that of smoke suppression, are easily and, on the whole, satisfactorily met by the use of the comparatively inexpensive solid fuels. On the other hand, the process of developing a supply of coal gas delivered from a central plant must involve not only the consumption of fuel, but also heavy added expense arising from fixed charges on the cost of a distant gas plant and its distributing pipe lines as well as from inefficiencies in the utilization of such facilities, which would appear in a varying load factor. For these reasons, it is believed that any plan to manufacture and distribute coal gas from a central source to all of the high pressure steam boiler service of the city of Chicago is, at this time, financially impracticable. A more immediate solution is likely to be found through local installations of gas producers serving individual boiler plants or closely associated groups of such plants.

115.06 Furnaces for Metallurgical, Manufacturing and Allied Processes: The furnaces for metallurgical, manufacturing and allied processes, are second in importance as sources of atmospheric pollution. They are charged with nearly one-third of the visible smoke and with two-thirds of the soot and dust which enter the atmosphere of Chicago. As already shown (section 105.31), a large portion of the solid constituents in such smoke is not of fuel origin. It consists of metallic substances which appear as waste in manufacturing processes.

In setting forth the extent of the atmospheric pollution arising from this service, it will be well to recognize the fact that the service is not uniformly distributed throughout the city but that it is well concentrated in a location south of the center of the city.

Any discussion of the possibilities of eliminating smoke from industrial fires must emphasize as a matter of first importance the significance of service conditions. These conditions are so widely diversified that no general formula governing procedure in smoke abatement is possible. It is this fact that makes the problem of abating smoke arising from metallurgical and other industrial fires one of the most difficult, if not the most difficult, presented by the fuel consuming activities of the city. Probably each one of the various procedures which have been set forth as being applicable to the abatement of smoke in high pressure steam boiler service may, under the varying conditions of practice, find some field of application in the maintenance of industrial fires. The automatic stoker and special forms of "smoke consuming" furnaces, the process of smoke washing, the process of electric precipitation, the possible substitution of fuel gas for solid fuels, and the possibility of transferring power loads from small steam plants to electric motors energized by current generated under conditions favorable to smoke abatement, may all aid in the solution of this problem.

Probably the most promising field of endeavor is that of encouraging an extension in the use of specially designed "smoke consuming" furnaces, of gas producers and of producer gas.

115.07 Steam Locomotives: Steam locomotives rank third among the smoke producing services. They are responsible for a little more than one-fifth of the visible smoke and for about one-twelfth of the solid constituents of smoke which pollute the atmosphere of Chicago. They present conditions which are simpler in some respects and more complex in others than those which are presented by the classes of service already discussed; they are simpler because all fires in locomotive service are maintained under conditions which are similar, and hence an improvement which can be applied to one becomes applicable to all; they are more complex because the intensity of the process of combustion which takes place in locomotive fire-boxes is exceptional. Devices which may easily be applied to the furnaces of stationary power plants find no room for development in connection with the furnaces of locomotives. Notwithstanding this fact, the art of smoke suppression in locomotive service is already well developed. In no other class of fuel consuming service are individual plants so generally equipped with approved devices for preventing smoke (section 114.07).

115.08 Low Pressure Steam and other Stationary Heating Plants: In Chicago approximately 4 per cent of the visible smoke and 9 per cent of the solid constituents of smoke may be attributed to fires sustaining low pressure steam and other stationary heating plants, which include all fires employed in domestic heating. This amount is small because the basis of comparison is the full calendar year. The seasonal variations in the amount of domestic smoke cover a wide range. For four months in the year no smoke is developed from such fires; for four other months the amount developed is comparatively small. The maximum emission of smoke from this service occurs during a comparatively short period of the year. An annual average of 4 per cent of visible smoke sent into the atmosphere of Chicago from this service implies a period of from two to four months, during which the contributions may be in excess of 15 or 20 per cent. During the period of its activity this service is, therefore, of far greater importance, as a source of atmospheric pollution, than would appear from the average values which have been set forth.

The solid constituents of smoke from domestic fires are relatively of greater importance as sources of atmospheric pollution than their percentage value indicates. This is due to their character. The solids of such fires, to a much greater extent than those from other fires, are composed of sooty and tarry particles which soil and stain far more than the ash or fuel particles resulting from other services. This fact, together with the seasonal peak in the load of this service, makes it one of the most important smoke producing services of the city.

One of the great difficulties encountered, in attempting to reduce the amount of smoke originating in domestic fires, grows out of the large number and the small size of the individual fires. Devices which may be applied with profit to large furnaces cannot at the present time be made serviceable in connection with domestic fires. Some investigators, in dealing with this aspect of the question, have sought to overcome the difficulty by bringing together the individual flues of many domestic fires into a single "smoke sewer" or chimney, the discharge of which would possess sufficient significance to justify some form of treatment. So far as is known, no real progress has been made in developing this method of smoke abatement.

Domestic fires constitute a peculiar service also, in that, as ordinarily maintained, they receive attention only at comparatively long intervals. This fact prohibits the employment of many forms of apparatus designed to control combustion, the use of which presupposes the continuous presence of an attendant. The fact also that the equipment used for heating is in service during a portion of the year only, further limits the character of the appliances with which a plant may be equipped.

Another possible method of abating smoke arising from domestic fires is to be found in the substitution of fuel gas for solid fuels. The arguments for such a substitution are better sustained in their application to domestic fires than in their application to the fires of most other services. The fact that, by using gas, the labor involved in the maintenance of coal fires is eliminated, as well as the objectionable dirt arising from the storage of coal and the disposal of ash, helps in justifying the higher cost of the gaseous fuel.

115.09 Allies of Smoke in Atmospheric Pollution: Attention has already been called to the secondary effects of the solid particles discharged in smoke which, having collected on exposed surfaces of the city, re-enter the atmosphere and, with dust not of fuel origin, add to the sum total of atmospheric dust. The relative value of dirt from all such sources, as compared with that directly emitted from chimneys, is not definitely known, but all the evidence points to the importance of these allies of smoke as factors in atmospheric pollution. Approximately one-third of the dirt in Chicago's atmosphere is not directly related to the discharge of chimneys. If all smoke were to cease at once, a considerable portion of present day dirt would still remain. The elimination of such dirt is a problem in city cleaning. Its significance has already been discussed (chapter 112). While no attempt has been made by the Committee to determine ways and means by which its polluting effects may be eliminated or reduced, it is obvious that any well defined program for the purification of the city's atmosphere cannot long neglect so important a source of pollution.

115.10 Advantages to be Derived from Research: The discussions of this report have, at various points, emphasized the scientific character of the city's problem of smoke abatement. One who undertakes a study of this problem soon discovers that reliable data derived from carefully conducted statistical studies or from engineering research, which are available for his use, are few. The real problem in smoke abatement is in fact not one of legislation or of inspection, but one of bringing together an enlarged fabric of facts concerning possibilities in the proper utilization of fuel, by which legislation and inspection may be safely guided.

Chicago has done well in providing a system of smoke inspection and in directing the activities of this bureau along educative lines. The city's department of smoke inspection has rendered good service to the public, but the work thus far accomplished has been limited in character and is insufficient to satisfy the urgent needs of the city. The activities of the department, which ought to be city wide, are now limited to a comparatively small portion of the total area of the city, and its program of procedure, which ought to include investigations highly scientific in character, does not, under present day conditions, permit the inclusion of such work. The city's next great step in its efforts to improve atmospheric conditions, more important than all which have thus far been taken, should be that of providing adequately for a permanently supported work of research. A pure air commission, supported by the municipality upon a scale commensurate with the needs of one of the world's great cities, would unravel and classify the complex characteristics of fuel; it would develop a more perfect definition of conditions to be observed in the use of each fuel; it would be serviceable in placing before every fuel user of the city a more perfect code governing his use of fuel; it would provide a permanent organization for the study of problems which are constantly changing; it would constitute a safe guide for new legislation; and it would make the city co-operatively helpful in the development of its largest business interest—its coal consuming industries.

PART II

TECHNICAL FEASIBILITY AND COST OF ELECTRIFYING THE RAILROAD TERMINALS OF CHICAGO

201. THE RAILROAD TERMINALS OF CHICAGO

SYNOPSIS: The railroad terminals of Chicago are extensive and they sustain traffic movements of unusual magnitude. This chapter constitutes a description of the terminals with particular reference to structures, rolling equipment, trackage and other facilities which will be affected by the introduction of any system of electrification.

201.01 General Description: The lines of the great trunk railroads having terminals in Chicago radiate from the city's business center much as the spokes of a giant wheel. Intersecting them, and affording direct and easy communication between all the railroads in the terminal district, are two belt railroads. A third intersecting belt road lies farther out, and provides additional facilities by means of which shipments may be directed around the city. Here and there, convenient to the plants which they serve, are located various industrial railroads. To the east of Chicago, connecting rail transportation with waters affording access to the sea, lie Lake Michigan and the other Great Lakes. To the south and east great industries are centered, the activities of some of which have found lodgment within the area of another state. A map of the vast establishment making up the railroad lines, yards and terminals of the Chicago District is elsewhere presented (section 201.16, fig. 329).

The continuous growth for several decades of the business and industrial activities of the Chicago District has resulted in a corresponding extension of railroad facilities. Each new line entering the city naturally sought a location not previously occupied, with the result that the district is intersected at rather uniform intervals by the main lines of railroads. Along these main lines have grown up many establishments for the handling of traffic and for the care of railroad equipment. These facilities include passenger terminals, freight terminals, motive power terminals, and railroad yards ranging in size from the small coach yard to the large freight switching and classification yard. These are some of the details which make the Chicago District the greatest center of railroad activity in the world. The mileage of railroad tracks in the Chicago District is sufficient to extend across the United States from the Atlantic to the Pacific. The railroad facilities constitute establishments which serve the convenience and necessities of 39 different railroad corporations. These railroads require, for their operation within the district, approximately 1,700 different locomotives daily, and they handle daily a sufficient number of freight cars to form a continuous line from Chicago to the Mississippi River, a distance of 250 miles. The city passenger terminals handle nearly 1,400 passenger trains every 24 hours.

Contiguous to the railroads of Chicago and having track connections with them, are more than 1,600 industries the requirements of which are such as to necessitate the shifting of many thousands of cars to or from their plants each day. To a single one of these, the Packing Industry, nearly 1,000 cars, on the average, are delivered daily, while several other industries are of such magnitude that the constant service of one or more locomotives is required in shifting cars within the limits of their plants. The industries of especial significance, from the standpoint of railroad activities, include the Union Stock Yards, between Halsted Street and Ashland Avenue from 39th Street to 47th Street; the Pullman Company, at Pullman; the Illinois Steel Company, at South Chicago and at North Avenue and the river; the Standard Oil Company, at Whiting, Ind.; the Indiana Steel Company, at Gary, Ind.; the By-Products Coke Corporation, at South Deering; the Universal Portland Cement Company, at Buffington, Ind.; the Corn Products Company, at Argo, Ill.; the American Car & Foundry Company, at Ashland Avenue and 22d Street; the Western Electric Company, at Hawthorne, Ill.; the International Harvester Company, at Deering, West Pullman and South Deering; and many others. Certain of these industries, such as the Pullman Company, the Western Electric Company and the International Harvester Company, require railroad facilities of such magnitude that it has been found expedient to incorporate them as industrial railroads.

201.02 Location of Railroad Lines and Establishments: When the Committee began its work, there was available no map showing the extent and character of the railroad establishments of Chicago. The need was such that it was early determined to produce a complete map of the city having special reference to the railroad establishments. To this end, all railroads operating within the Area of Investigation filed with the Committee maps of their lines on which were shown all tracks, buildings and other facilities owned by them. From these maps tracings were prepared on a uniform scale of 400 feet to one inch, showing all railroad tracks, buildings adjacent thereto, and principal auxiliary features such as street lines, rivers and parks. These tracings were made in sheets, each embracing four land sections, or four square miles. In addition to the maps furnished by the railroad companies, maps prepared by the United States Government, by Cook County and by the city of Chicago have been freely consulted with regard to special features. In many instances representatives of the Committee made inspections for the purpose of verifying information shown on the maps. Each railroad track is indicated by a single line, and features which might detract from the clearness of track lay-out are omitted. Among such omitted features may be mentioned bridges, right-of-way lines and subdivision lines. From the tracings thus prepared, engravings were made to a scale of 800 feet to an inch, for that portion of Chicago lying between Belmont Avenue on the north and 103d Street on the south, each engraving representing one land section, or one square mile. These engravings constitute a railroad atlas of Chicago. They are presented as figs. 94 to 245, inclusive, fig. 94 being an index map showing the location of the various sections covered by subsequent maps. All of these maps were prepared on the basis of conditions existing in the Committee's statistical year, 1912.

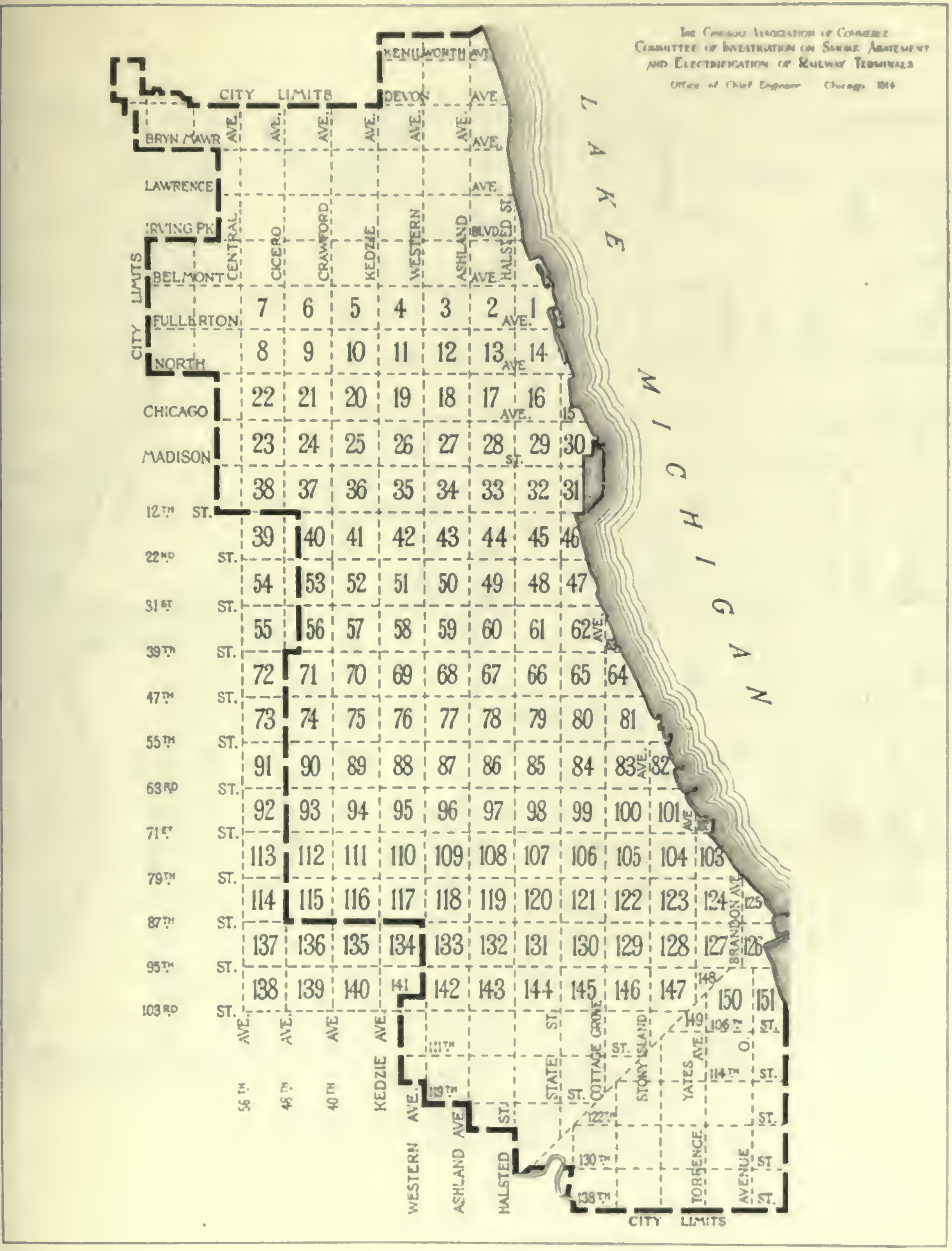

FIG. 94. INDEX MAP OF THE CITY OF CHICAGO

(The numbers on this Map refer to Detailed Maps of Sections which follow, figs. 95 to 245 inclusive)

FIG: 95. SECTION MAP, INDEX NO. 1

Fractional Section 28—Twp. 40 N.—R. 14 E.—3 P. M. Scale: 1″=800′

FIG. 96. SECTION MAP, INDEX NO. 2

Section 29—Twp. 40 N.—R. 14 E.—3 P. M. Scale: 1″=800′

FIG. 97. SECTION MAP, INDEX NO. 3
Section 30—Twp. 40 N.—R. 14 E.—3 P. M. Scale: 1″=800′

FIG. 98. SECTION MAP, INDEX NO. 4

Section 25—Twp. 40 N.—R. 13 E.—3 P. M. Scale: 1″ = 800′

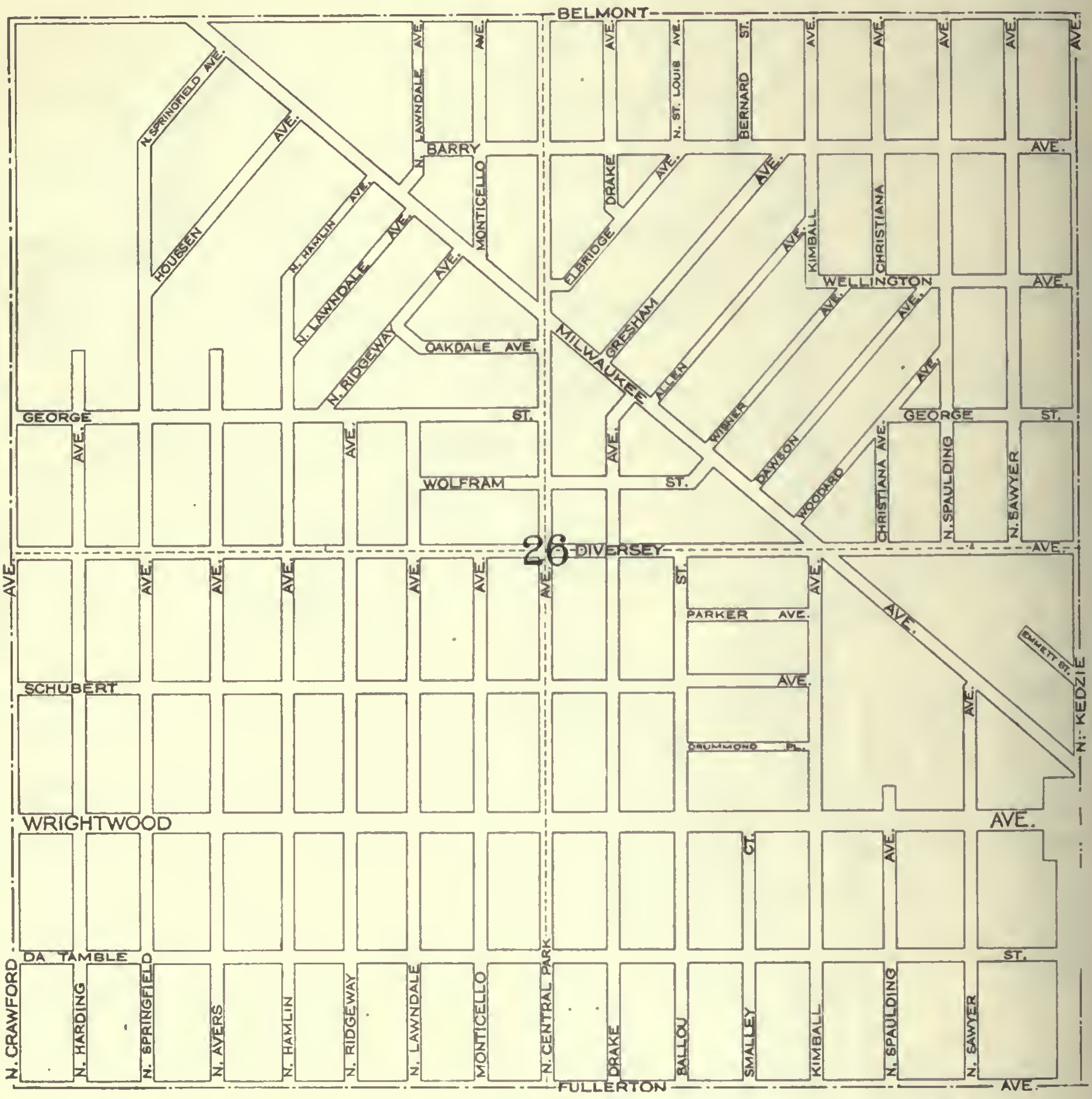

FIG. 99. SECTION MAP, INDEX NO. 5

Section 26 —Twp. 40 N.— R. 13 E.— 3 P. M. Scale: 1″ = 800′

FIG. 100. SECTION MAP, INDEX NO. 6

Section 27— Twp. 40 N.— R. 13 E.— 3 P. M. Scale: 1″ = 800′

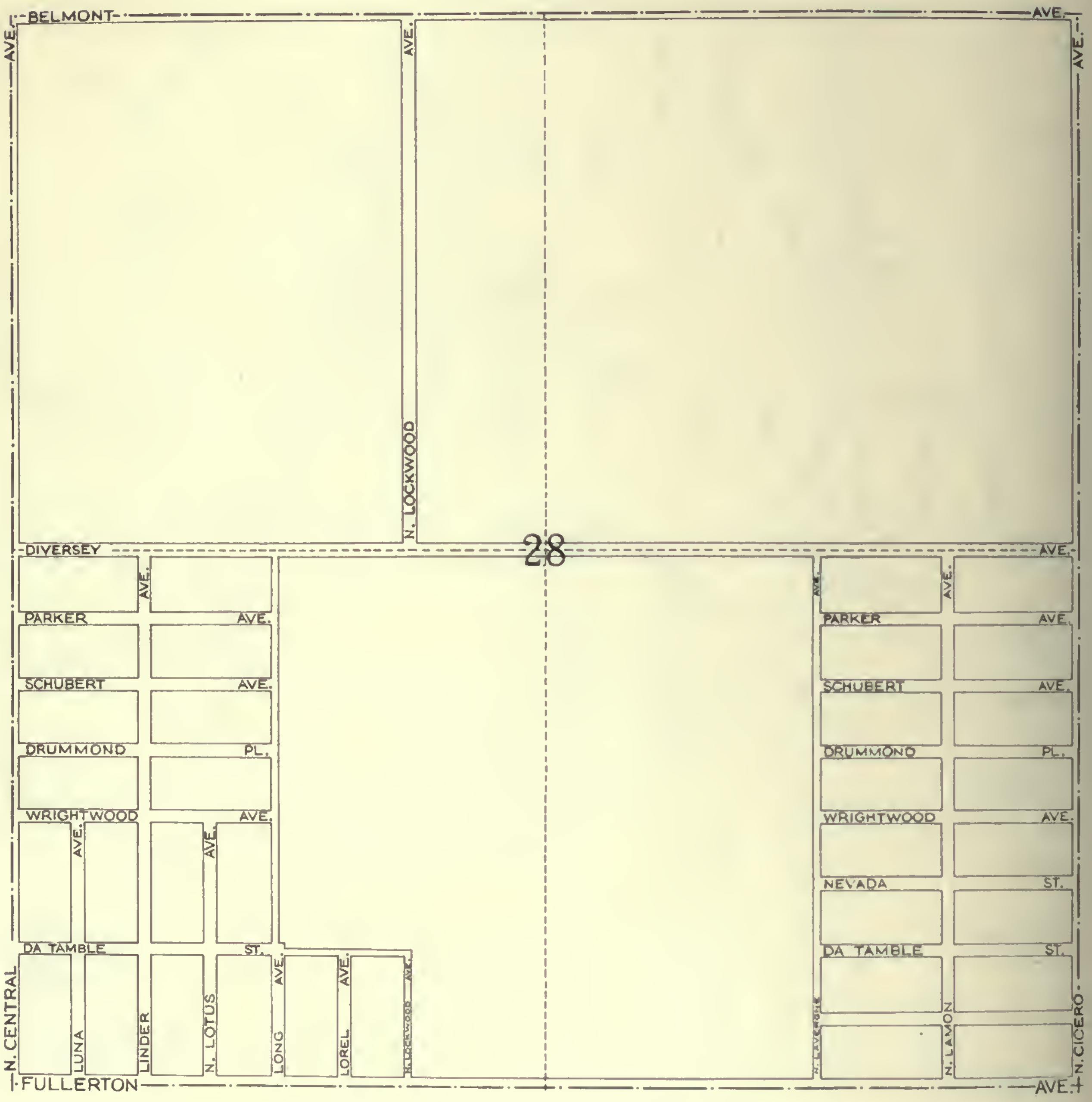

FIG. 101. SECTION MAP, INDEX NO. 7
Section 28 — Twp. 40 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

FIG. 102. SECTION MAP, INDEX NO. 8
Section 33—Twp. 40 N.— R. 13 E.—3 P. M. Scale: 1″=800′

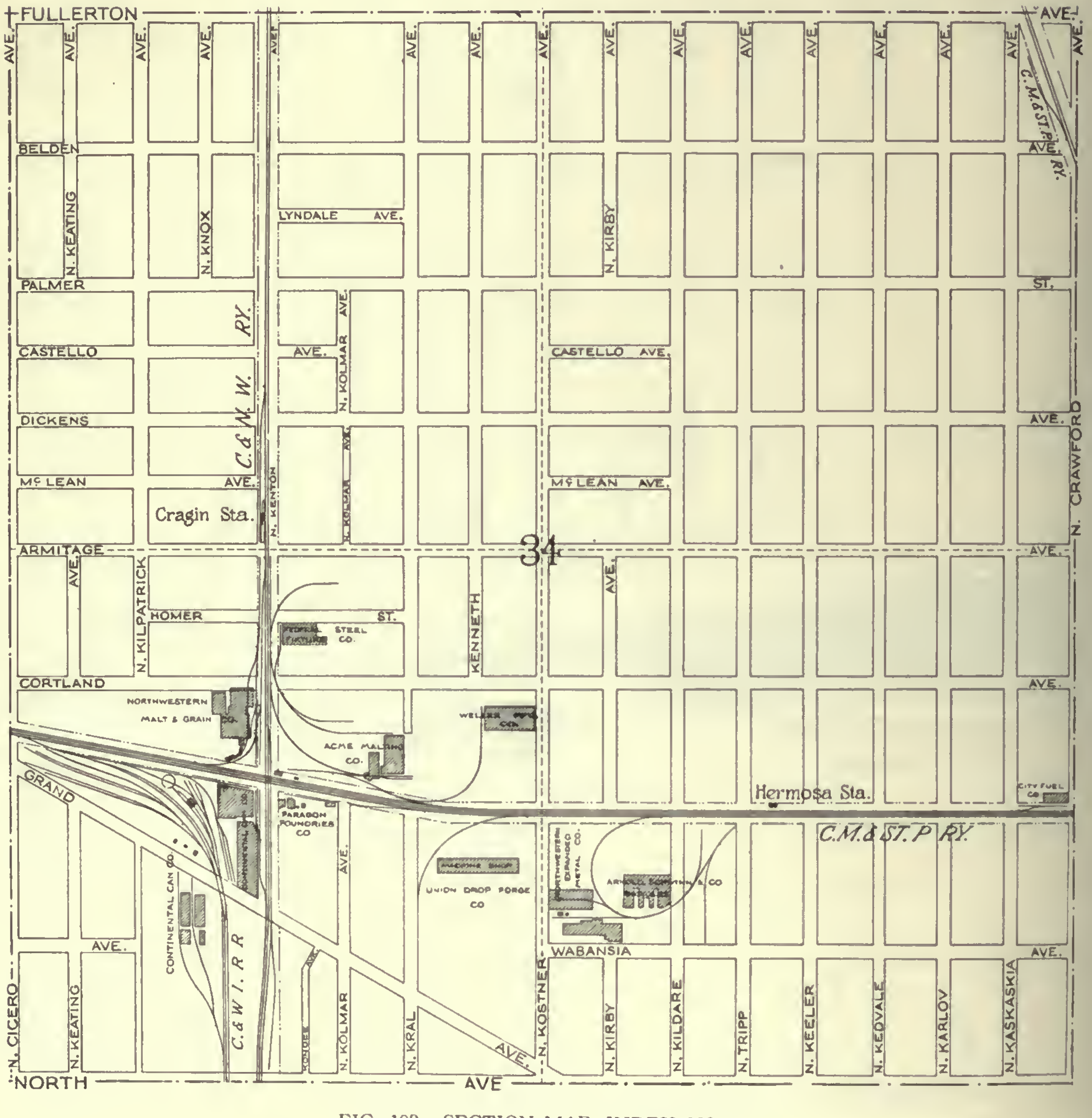

FIG. 103. SECTION MAP, INDEX NO. 9

Section 34—Twp. 40 N.— R. 13 E.— 3 P. M. Scale: 1″=800′

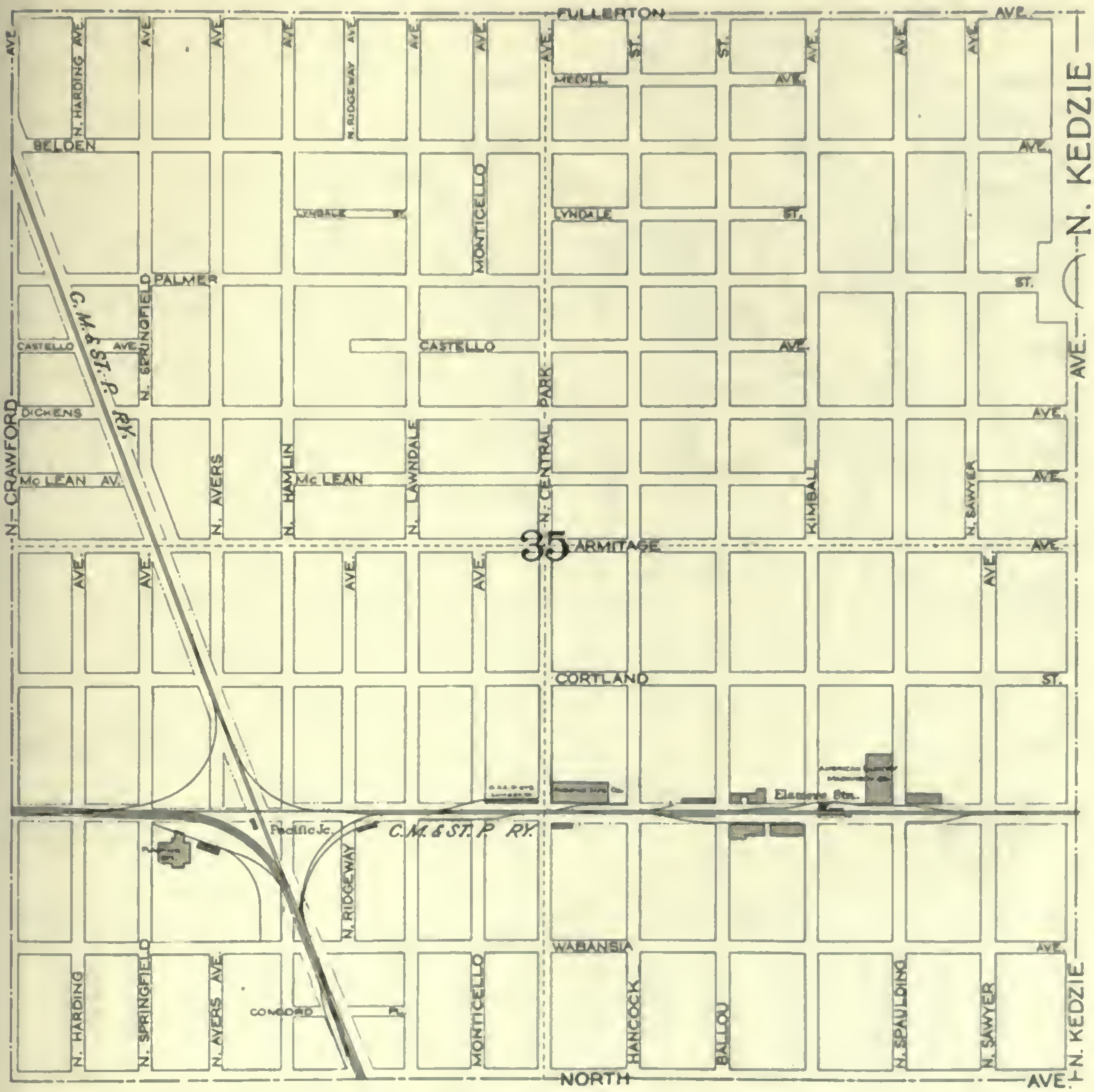

FIG. 104. SECTION MAP, INDEX NO. 10

Section 35—Twp. 40 N.— R. 13 E.—3 P. M. Scale: 1″=800′

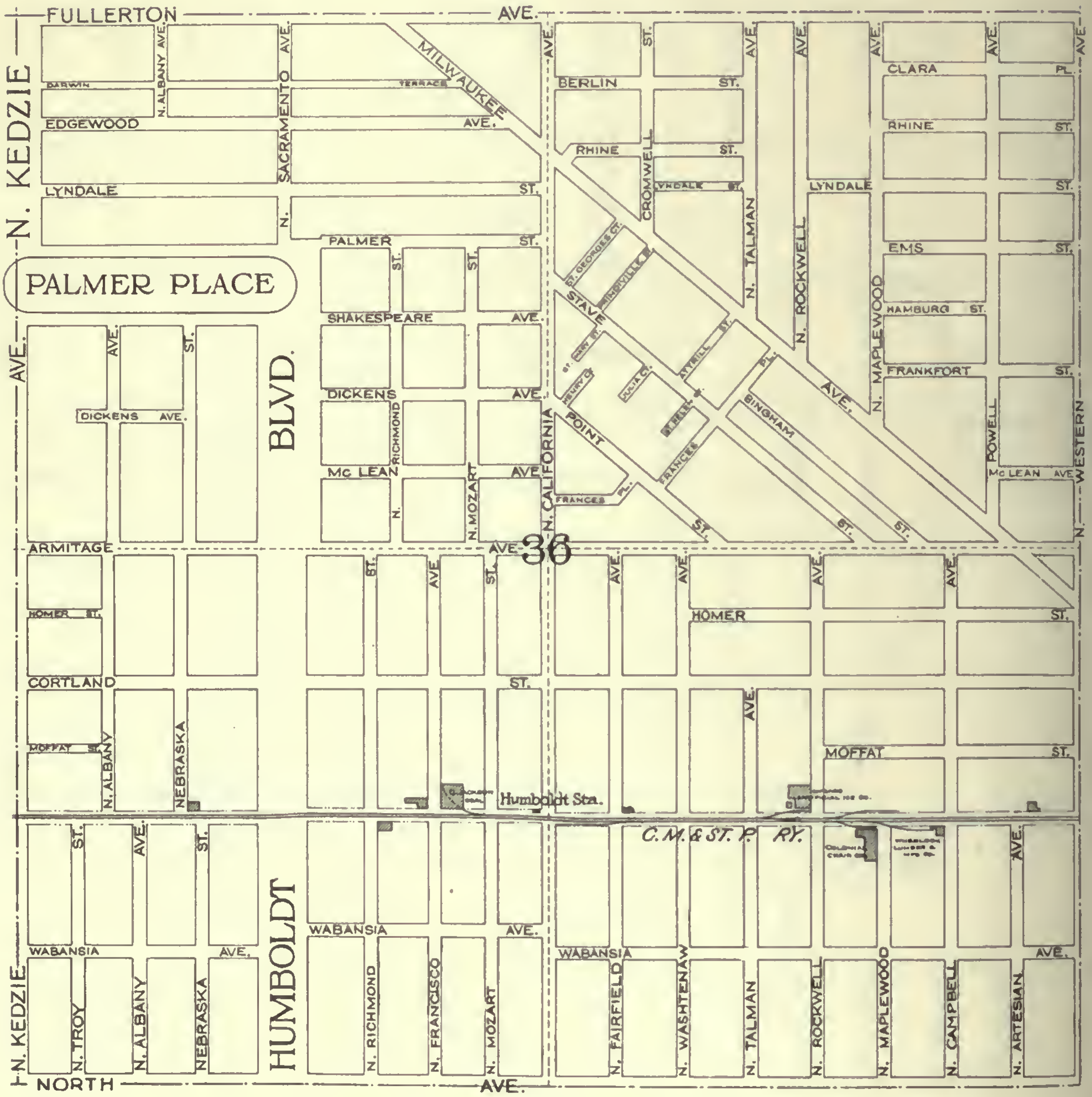

FIG. 105. SECTION MAP, INDEX NO. 11
Section 36—Twp. 40 N.— R. 13 E.— 3 P. M. Scale: 1″=800′

FIG. 105. SECTION MAP, INDEX NO. 12

Section 31 — Twp. 40 N. — R. 14 E. — 3 P. M. Scale: 1" = 800'

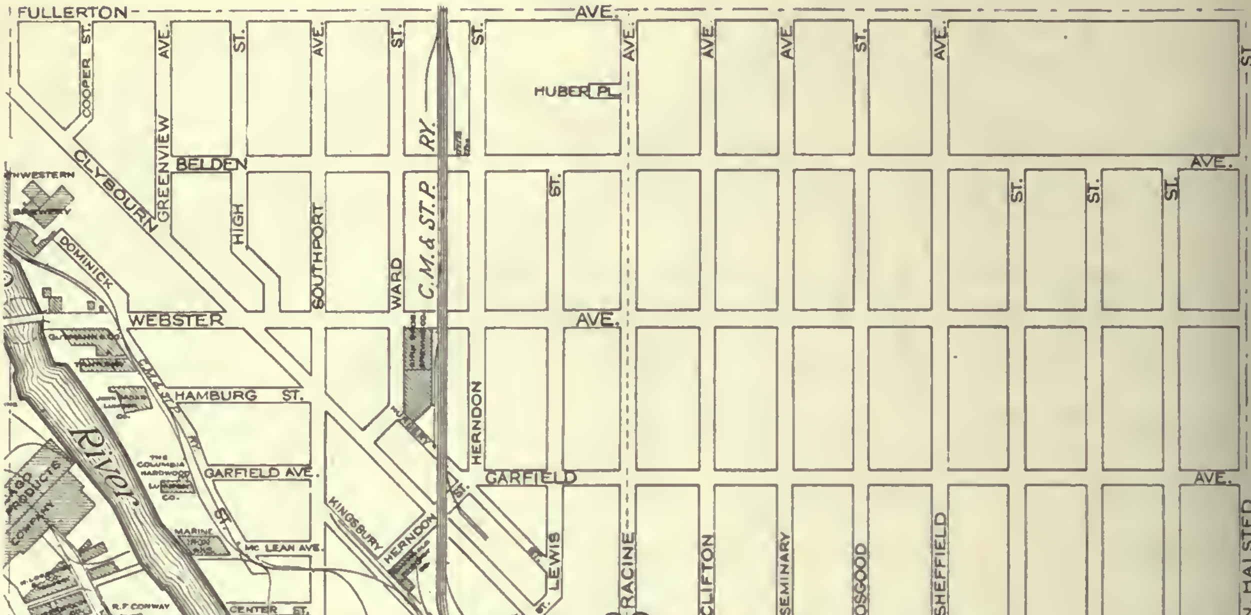

FIG. 107. SECTION MAP, INDEX NO. 13

Section 32 — Twp. 40 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

FIG. 108. SECTION MAP, INDEX NO. 14
Fractional Sections 33 and 34 — Twp. 40 N.—R. 14 E.—3 P. M. Scale: 1″ = 800′

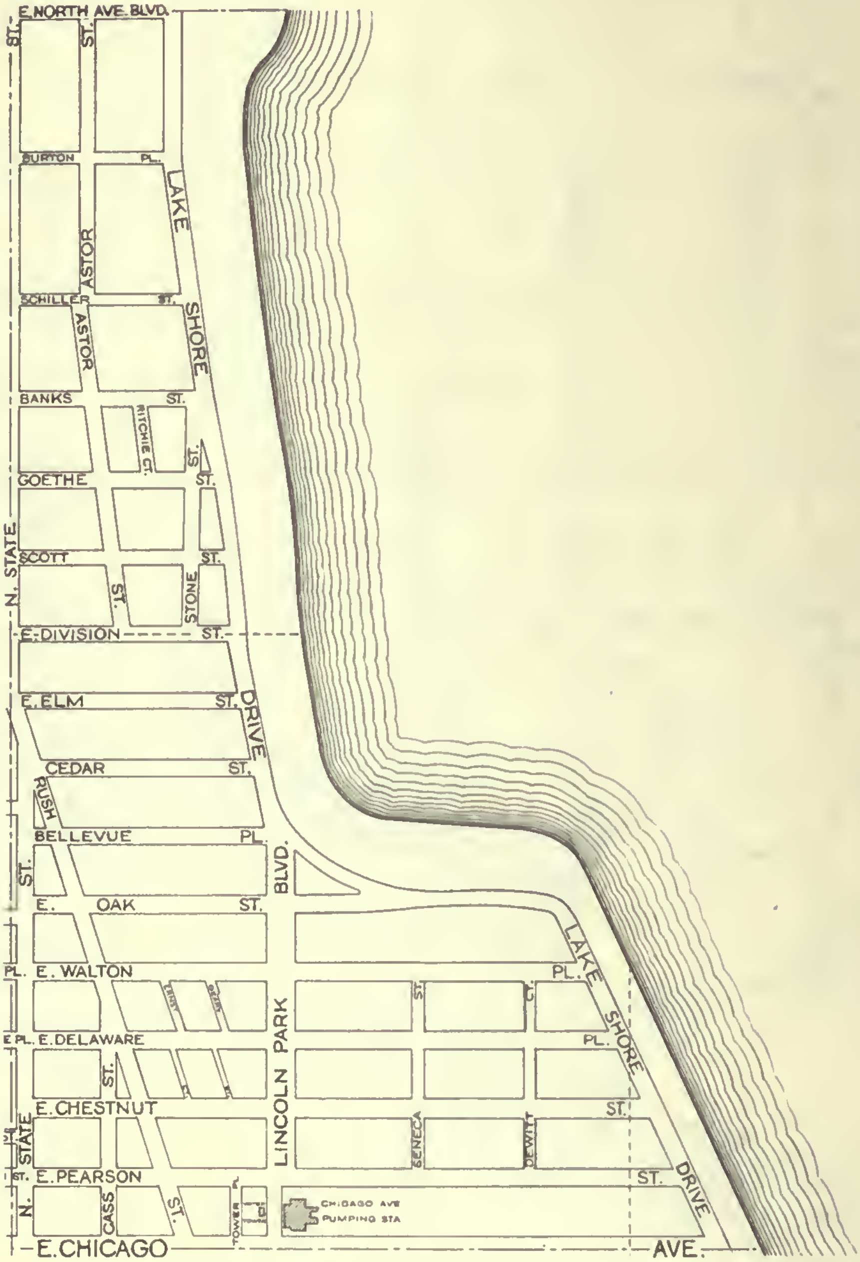

FIG. 109. SECTION MAP, INDEX NO. 15

Fractional Section 3—Twp. 39 N.—R. 14 E.—3 P. M. Scale: 1″=800′

FIG. 110. SECTION MAP, INDEX NO. 16
Section 4 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

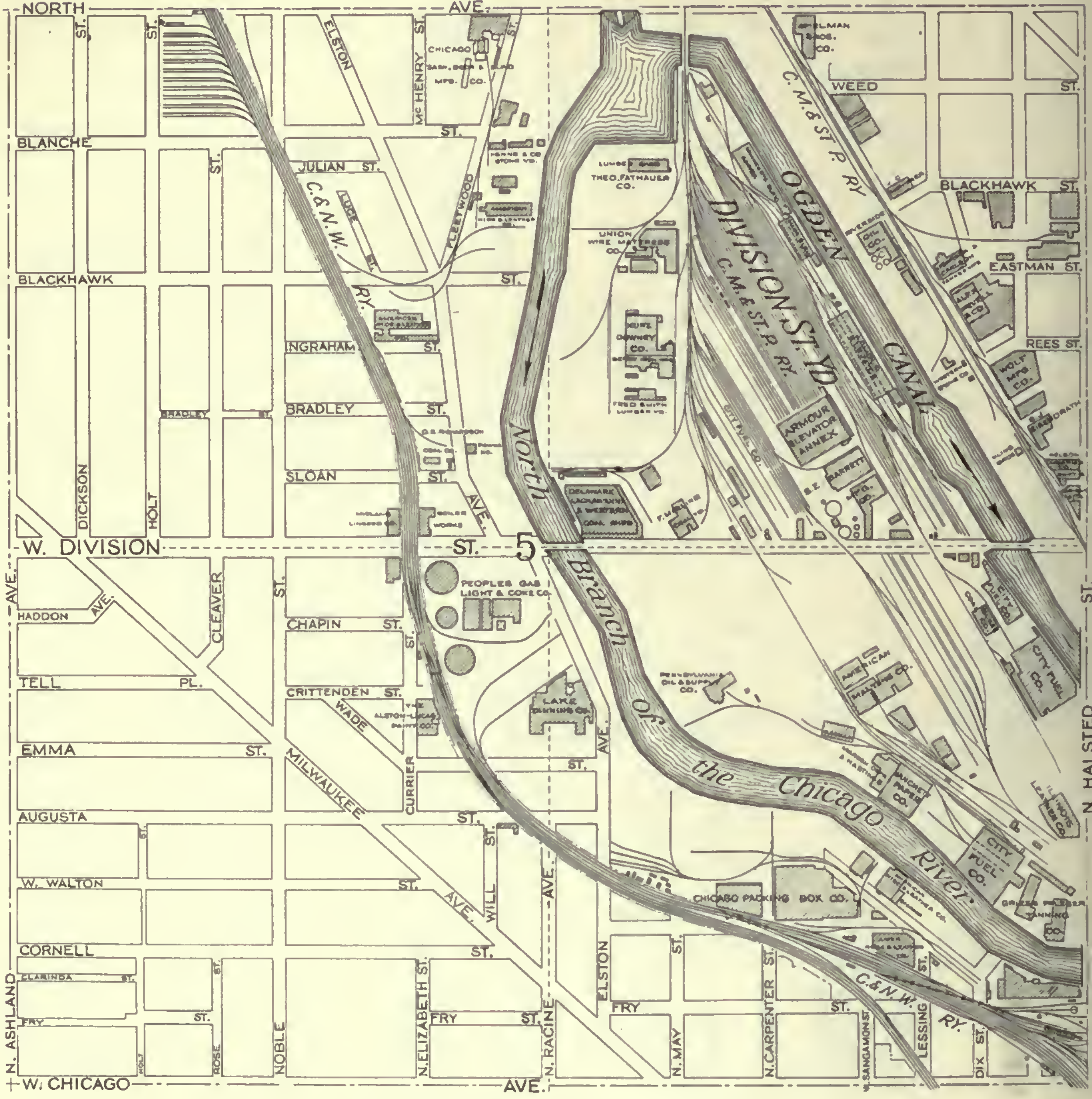

FIG. 111. SECTION MAP, INDEX NO. 17

Section 5 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

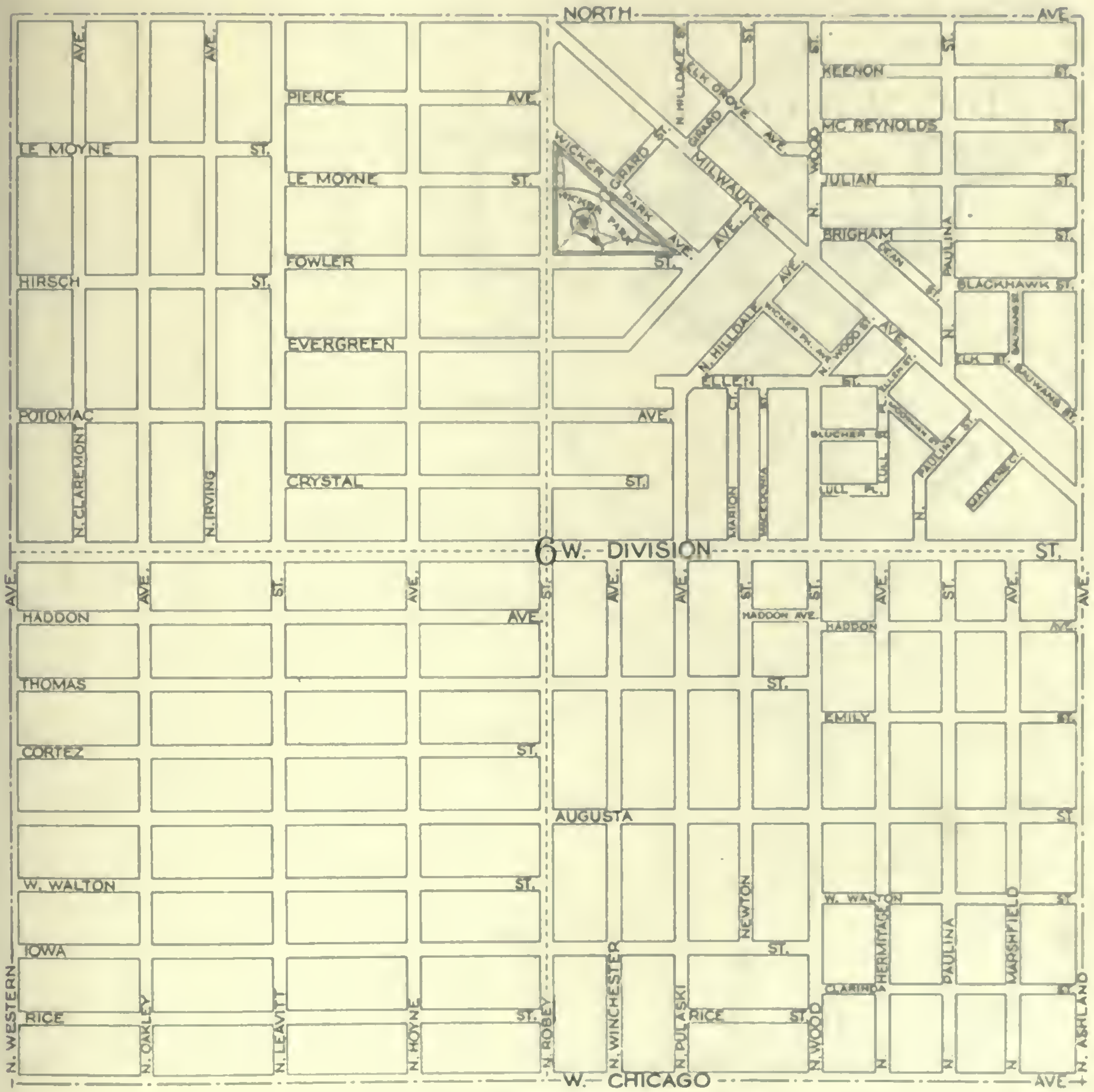

FIG. 112. SECTION MAP, INDEX NO. 18

Section 6 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

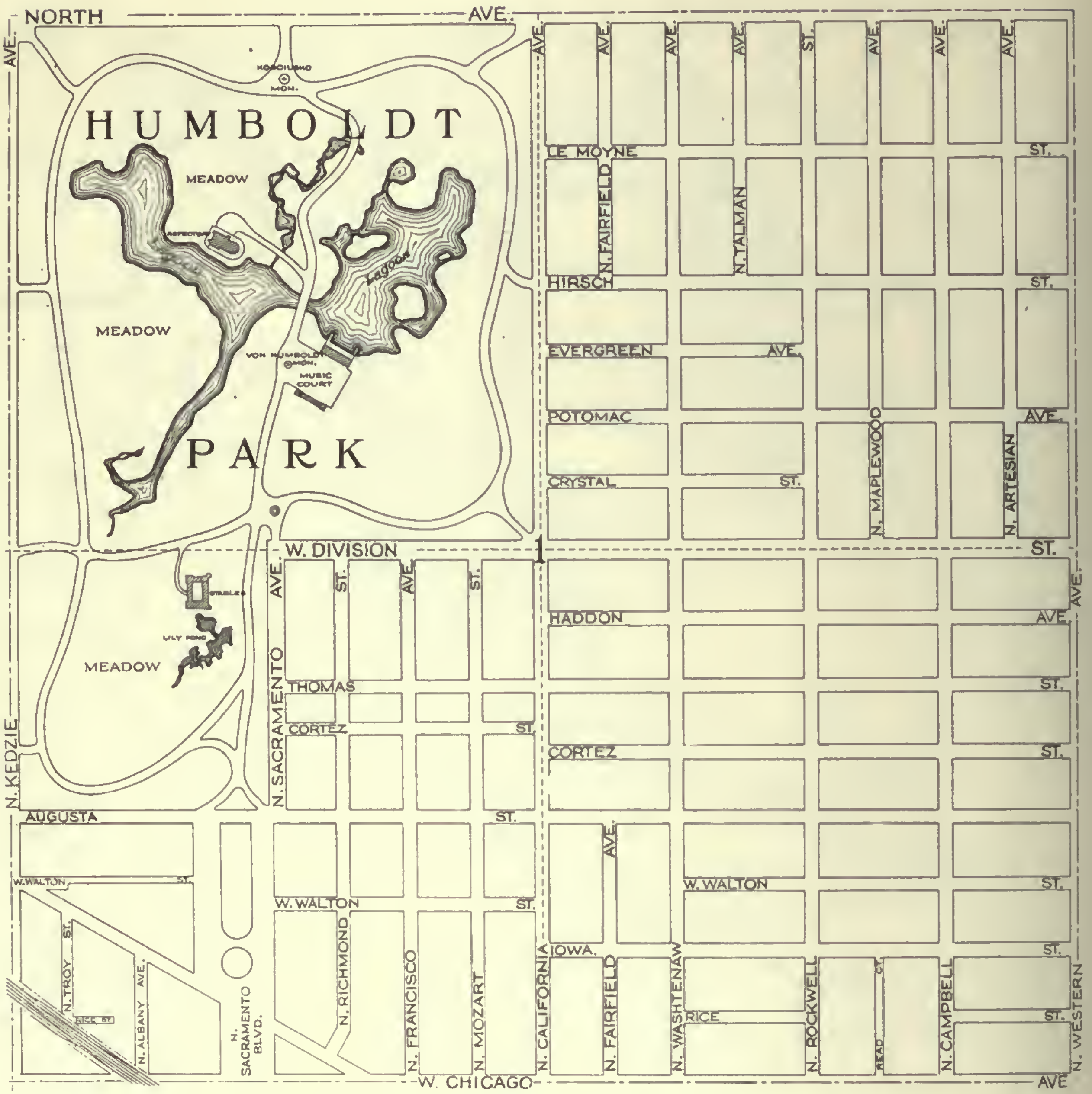

FIG. 113. SECTION MAP, INDEX NO. 19

Section 1 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″=800′

FIG. 114. SECTION MAP, INDEX NO. 20

Section 2 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1" = 800'

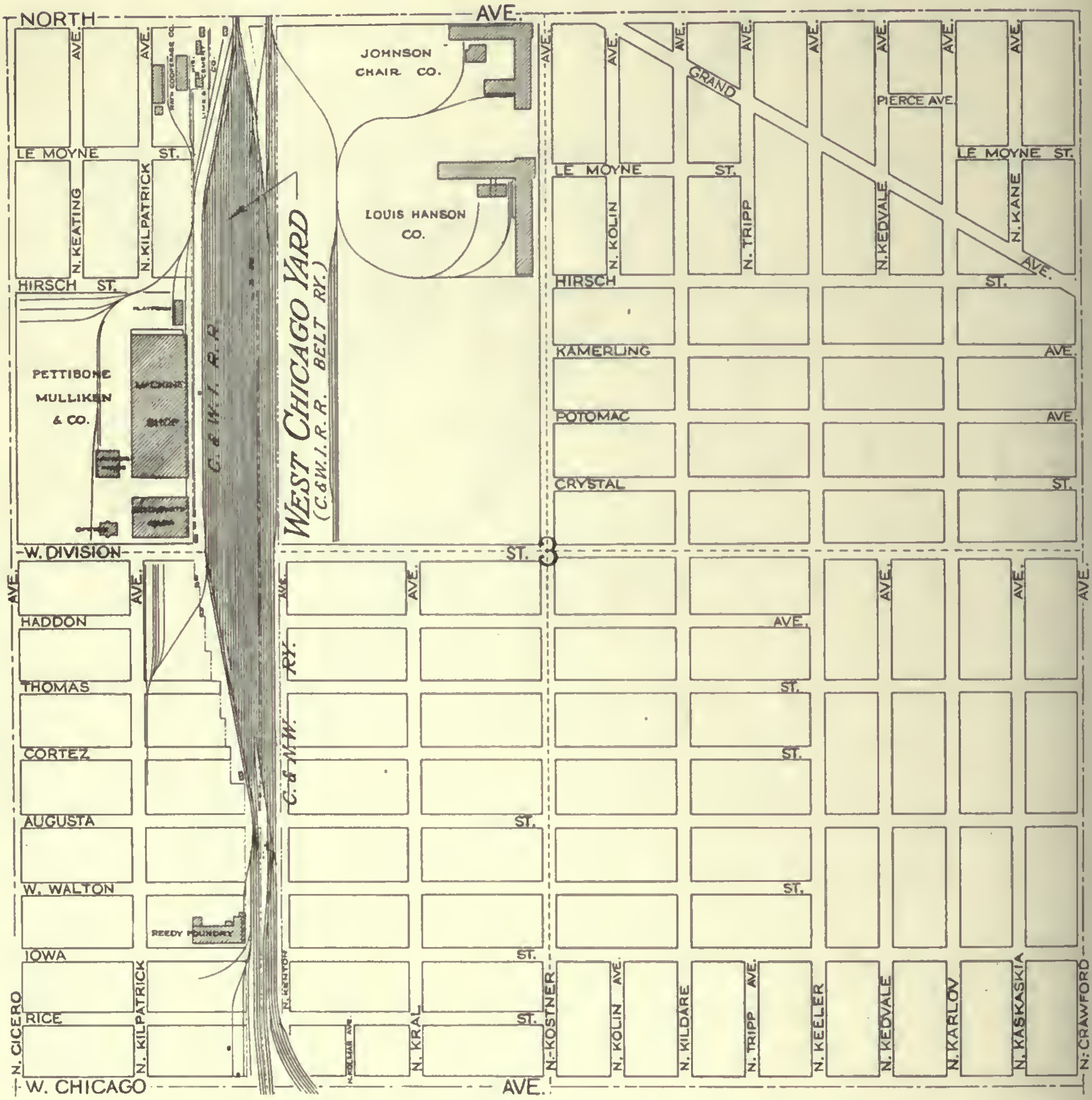

FIG. 115. SECTION MAP, INDEX NO. 21

Section 3 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

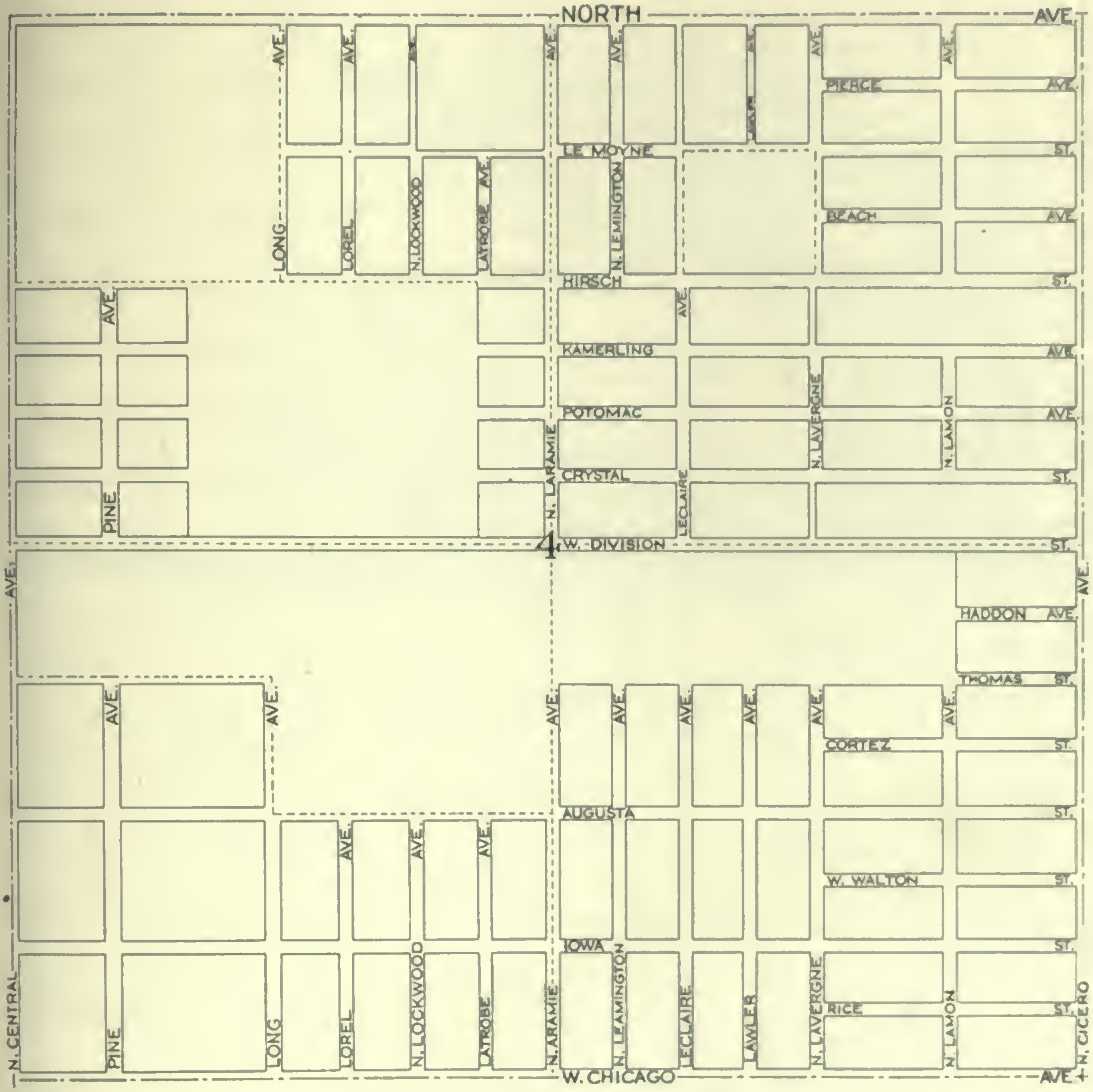

FIG. 116. SECTION MAP, INDEX NO. 22

Section 4 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

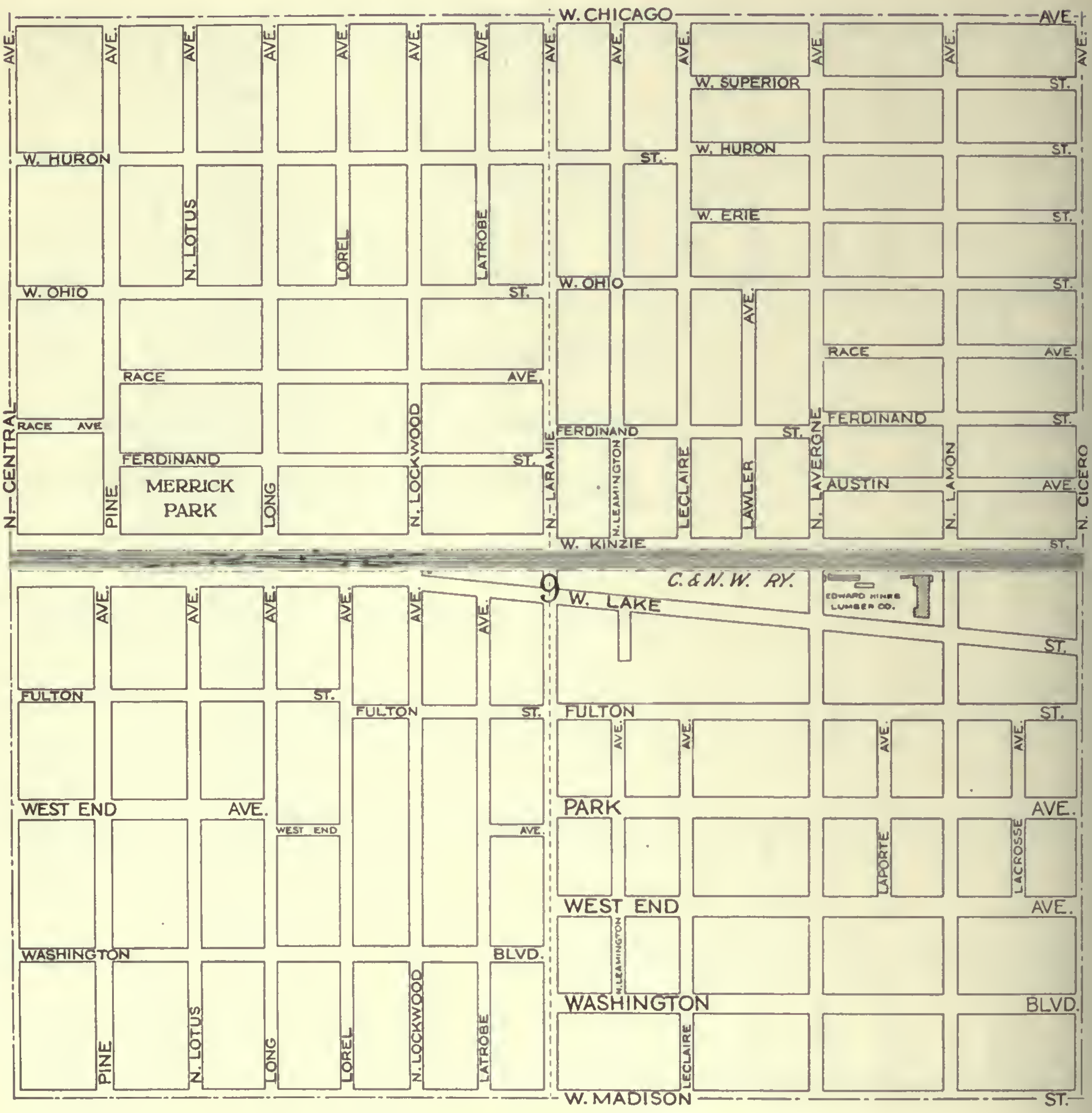

FIG. 117. SECTION MAP, INDEX NO. 23

Section 9 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

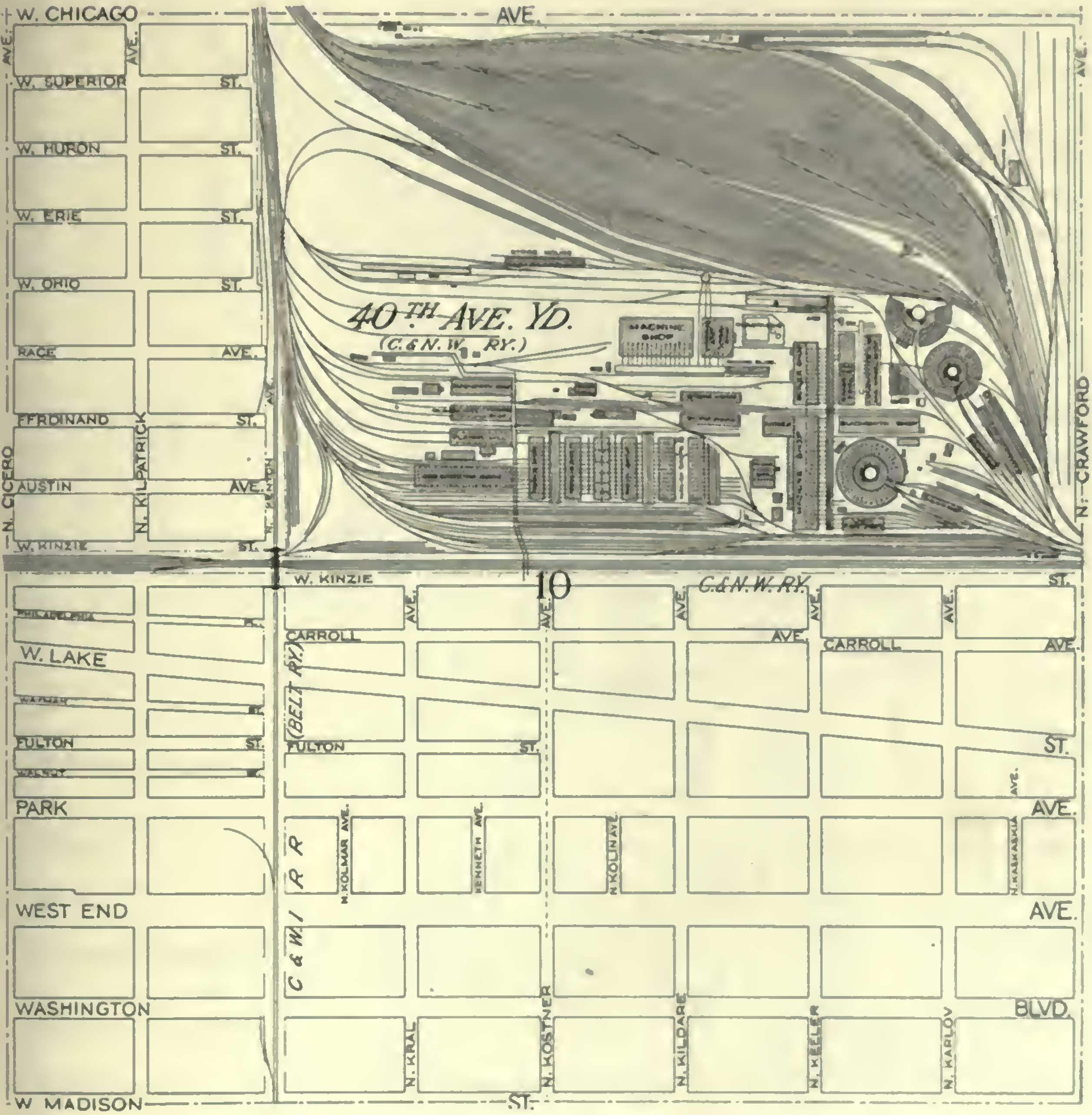

FIG. 118. SECTION MAP, INDEX NO. 24

Section 10 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

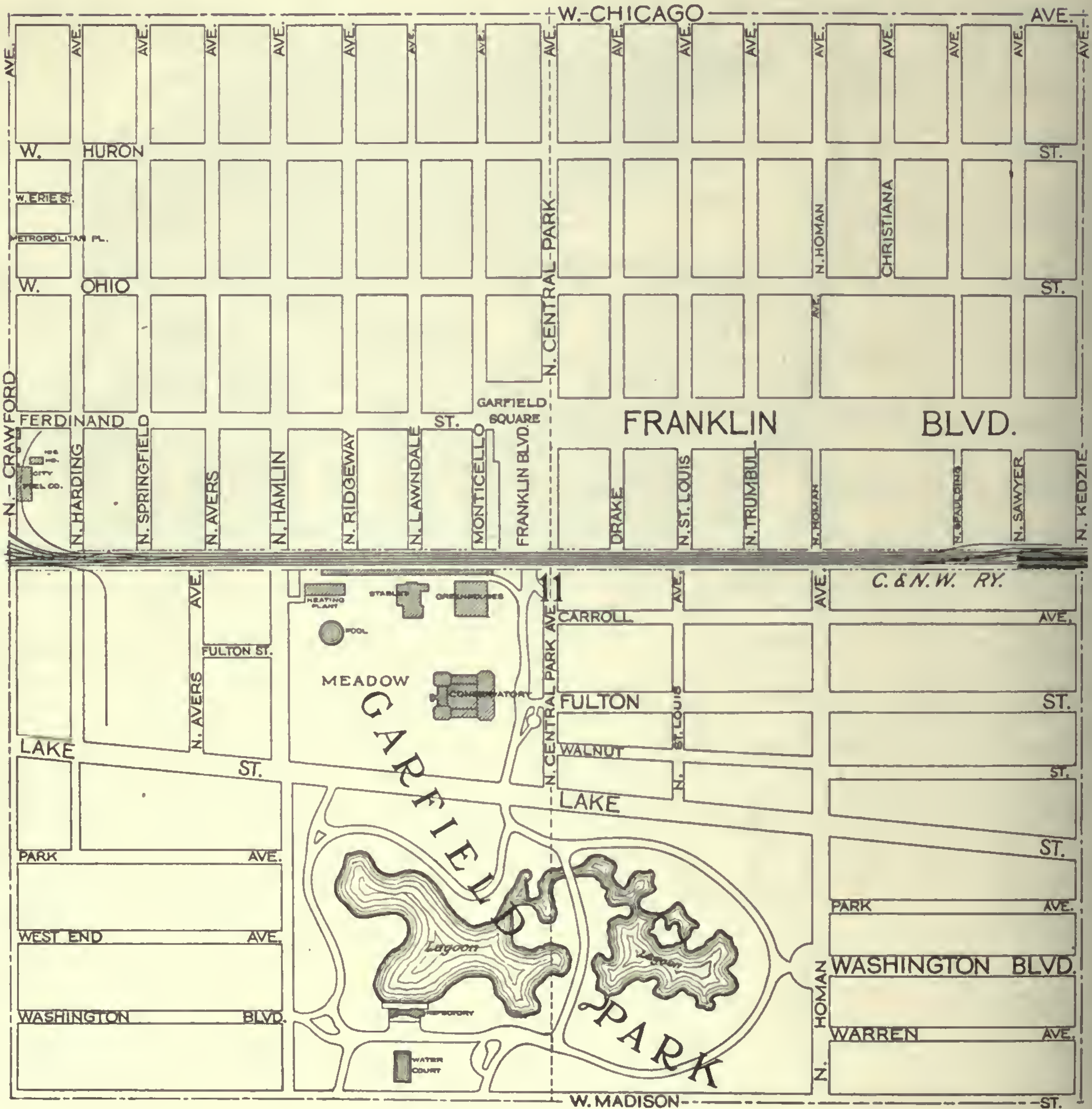

FIG. 119. SECTION MAP, INDEX NO. 25
Section 11 — Twp. 39 N.— R. 13 E. — 3 P. M. Scale: 1″=800′

FIG. 120. SECTION MAP, INDEX NO. 26

Section 12 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

FIG. 121. SECTION MAP, INDEX NO. 27

Section 7 — Twp. 39 N — R. 14 E. — 3 P. M. Scale: 1″=800′

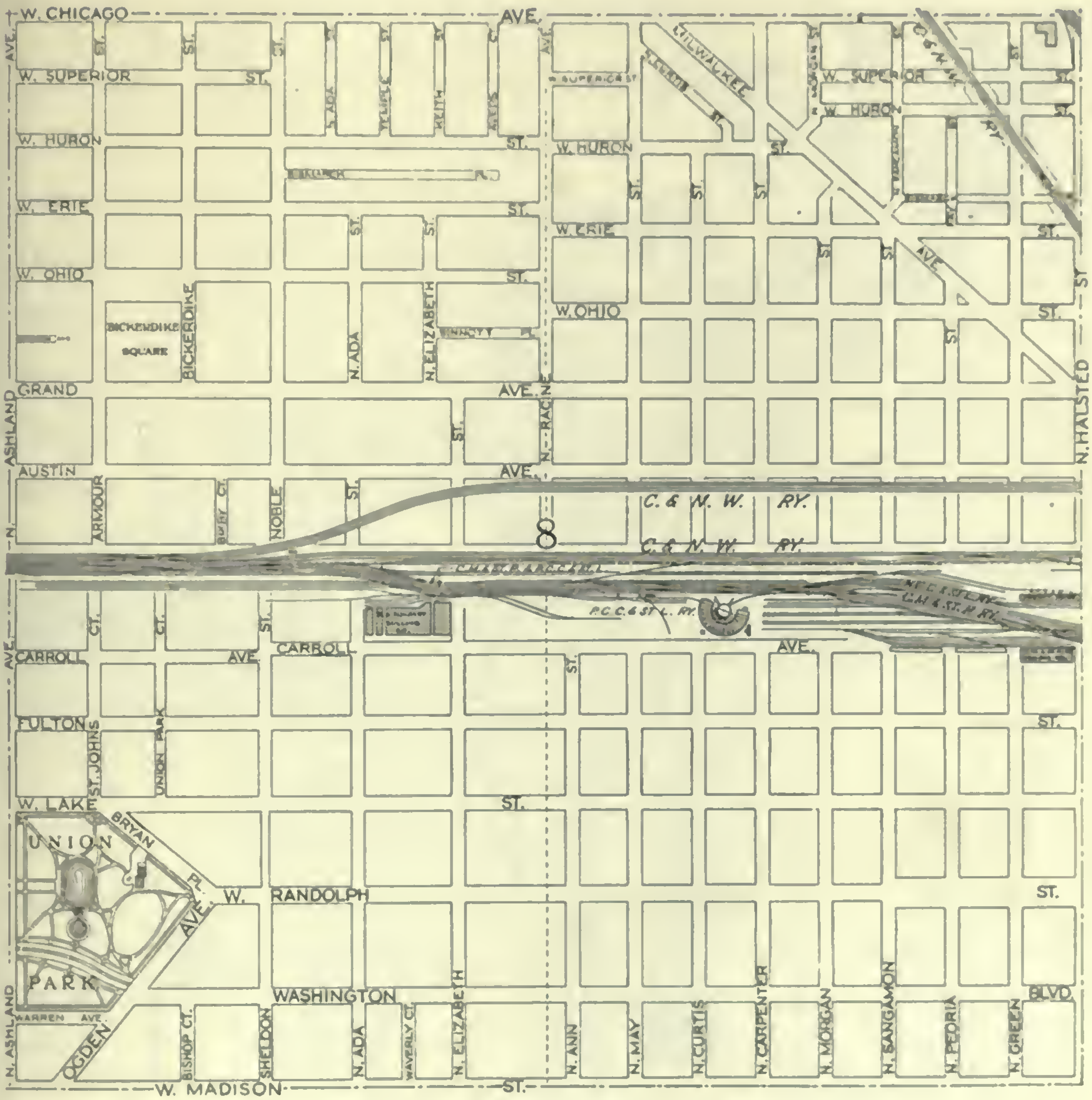

FIG. 122. SECTION MAP, INDEX NO. 28

Section 8 — Twp. 39 N.—R. 14 E.—3 P. M. Scale: 1″ = 800′

FIG. 123. SECTION MAP, INDEX NO. 29

Section 9 — Twp. 39 N.— R. 14 E.— 3 P. M. Scale: 1″ = 800′

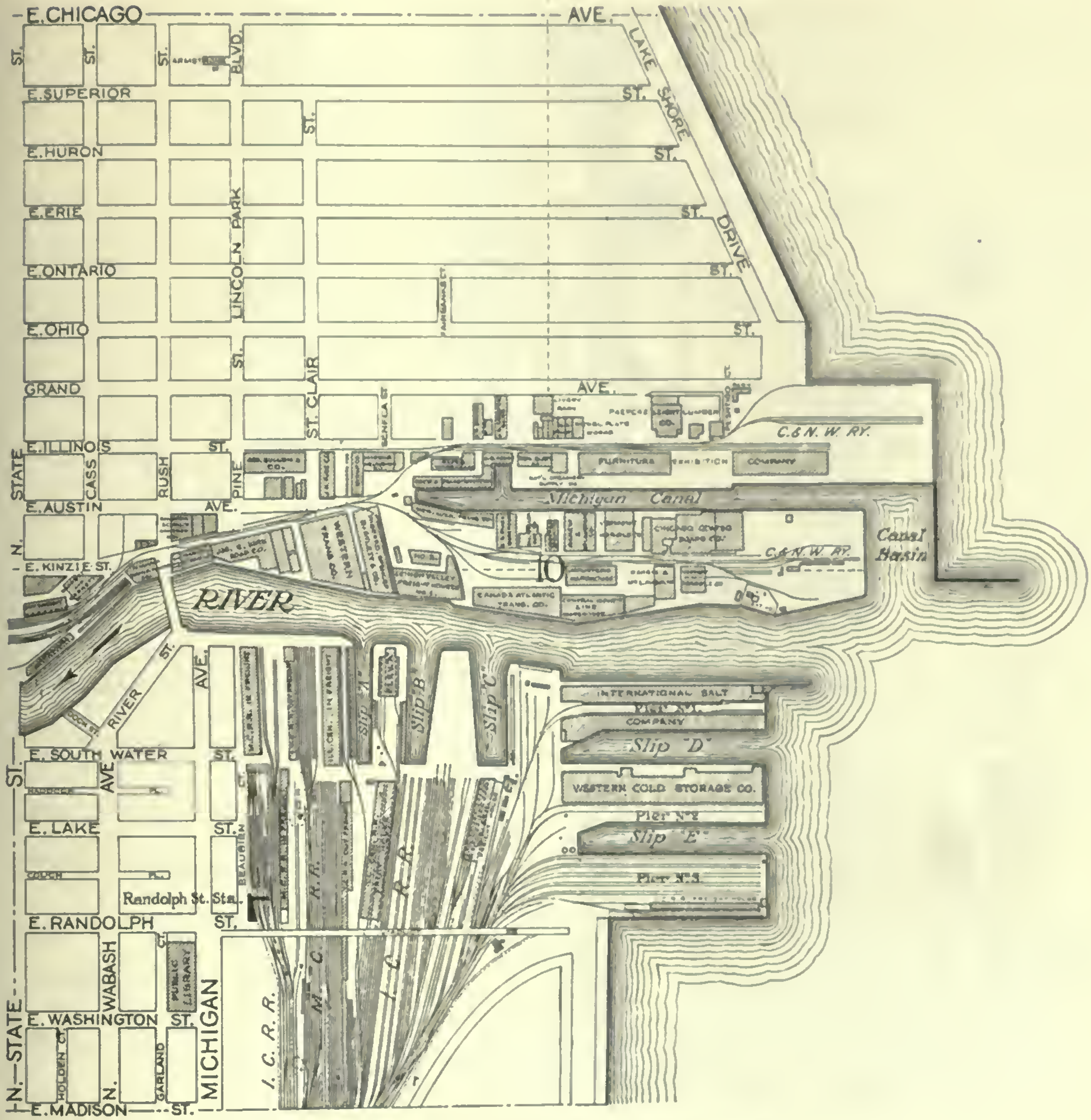

FIG. 124. SECTION MAP, INDEX NO. 30

Fractional Section 10 — Twp. 39 N.— R. 14 E.— 3 P. M. Scale: 1″ = 800′

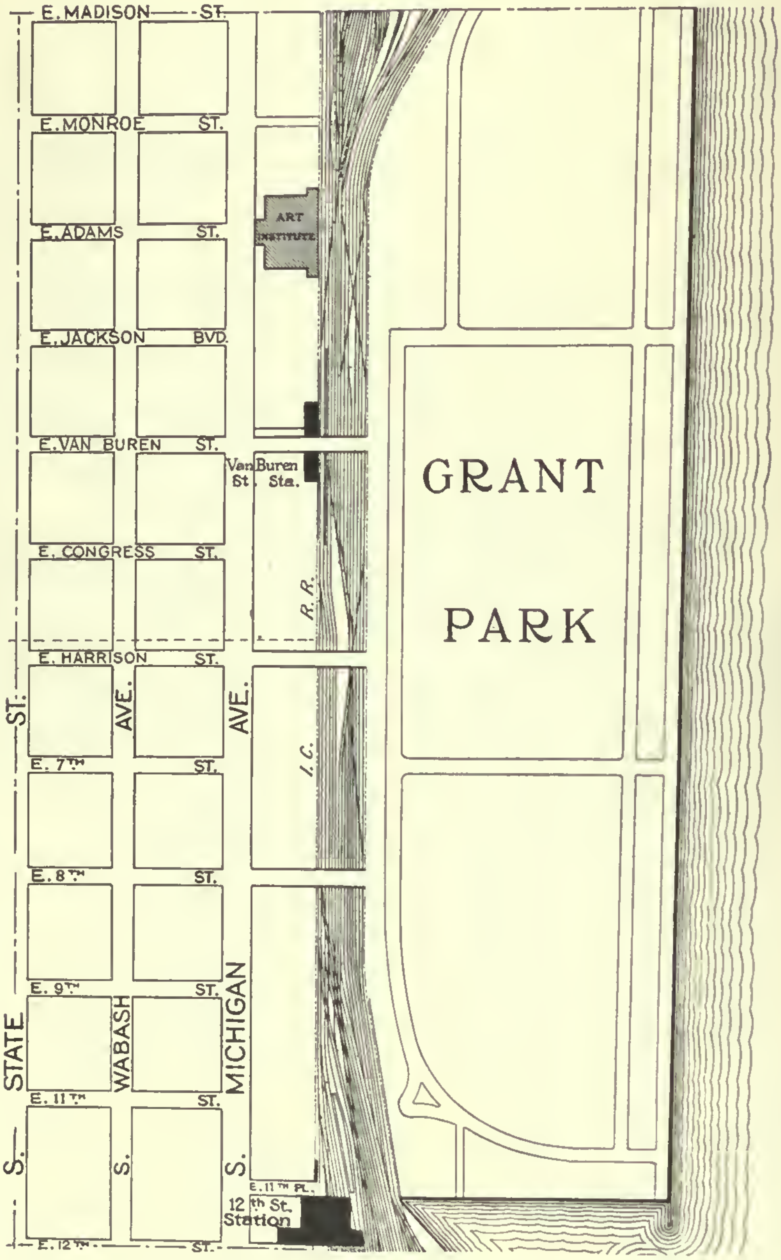

FIG. 125. SECTION MAP, INDEX NO. 31
Fractional Section 15 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

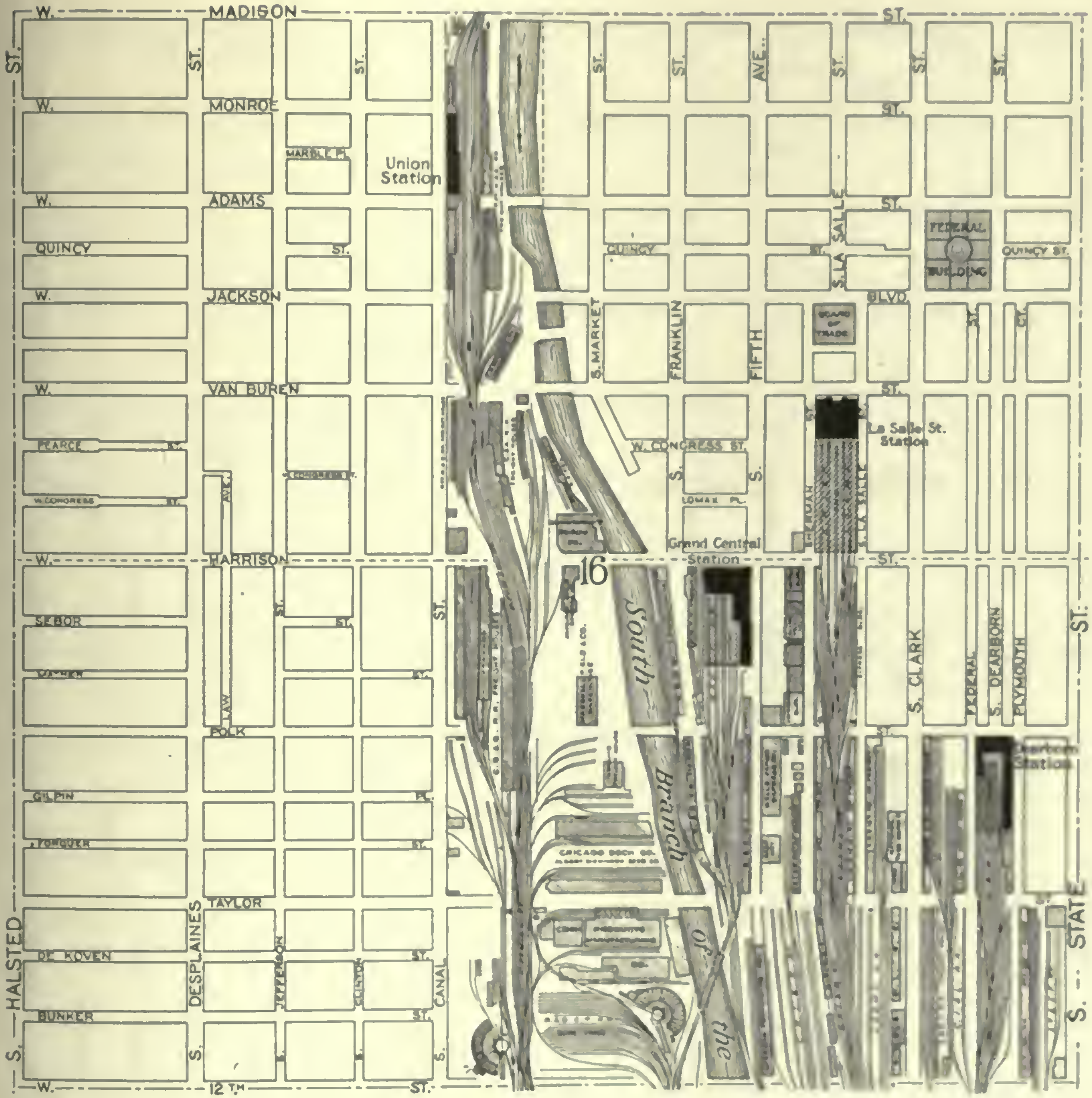

FIG. 126. SECTION MAP, INDEX NO. 32
Section 16 — Twp. 39 N. — R. 14 E — 3 P. M. Scale: 1" = 800'

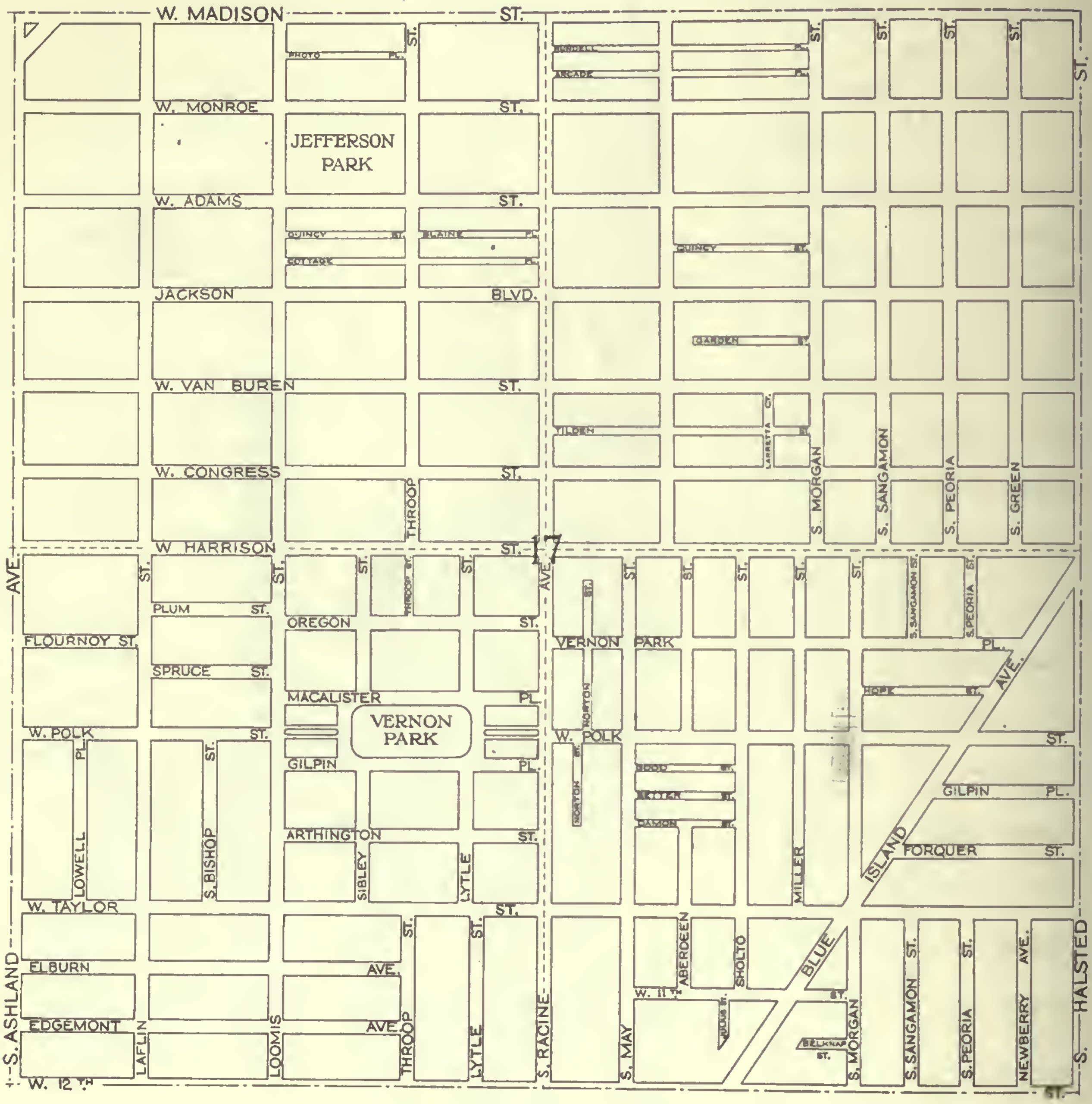

FIG. 127. SECTION MAP, INDEX NO. 33

Section 17 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″=800′

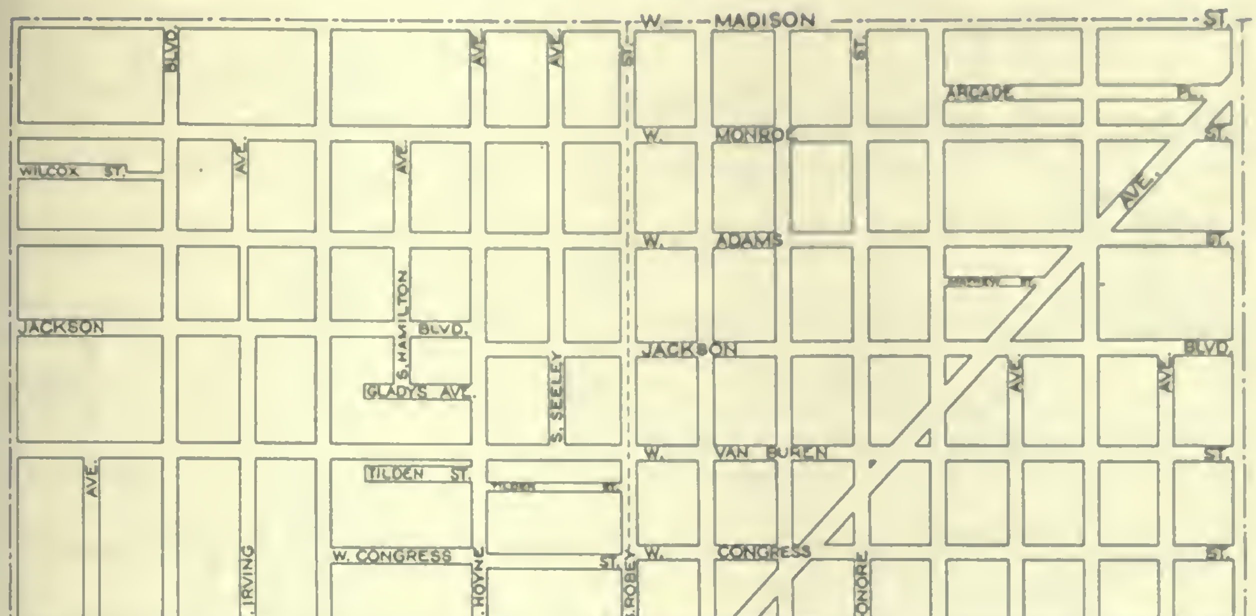

FIG. 128. SECTION MAP, INDEX NO. 34

Section 18 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

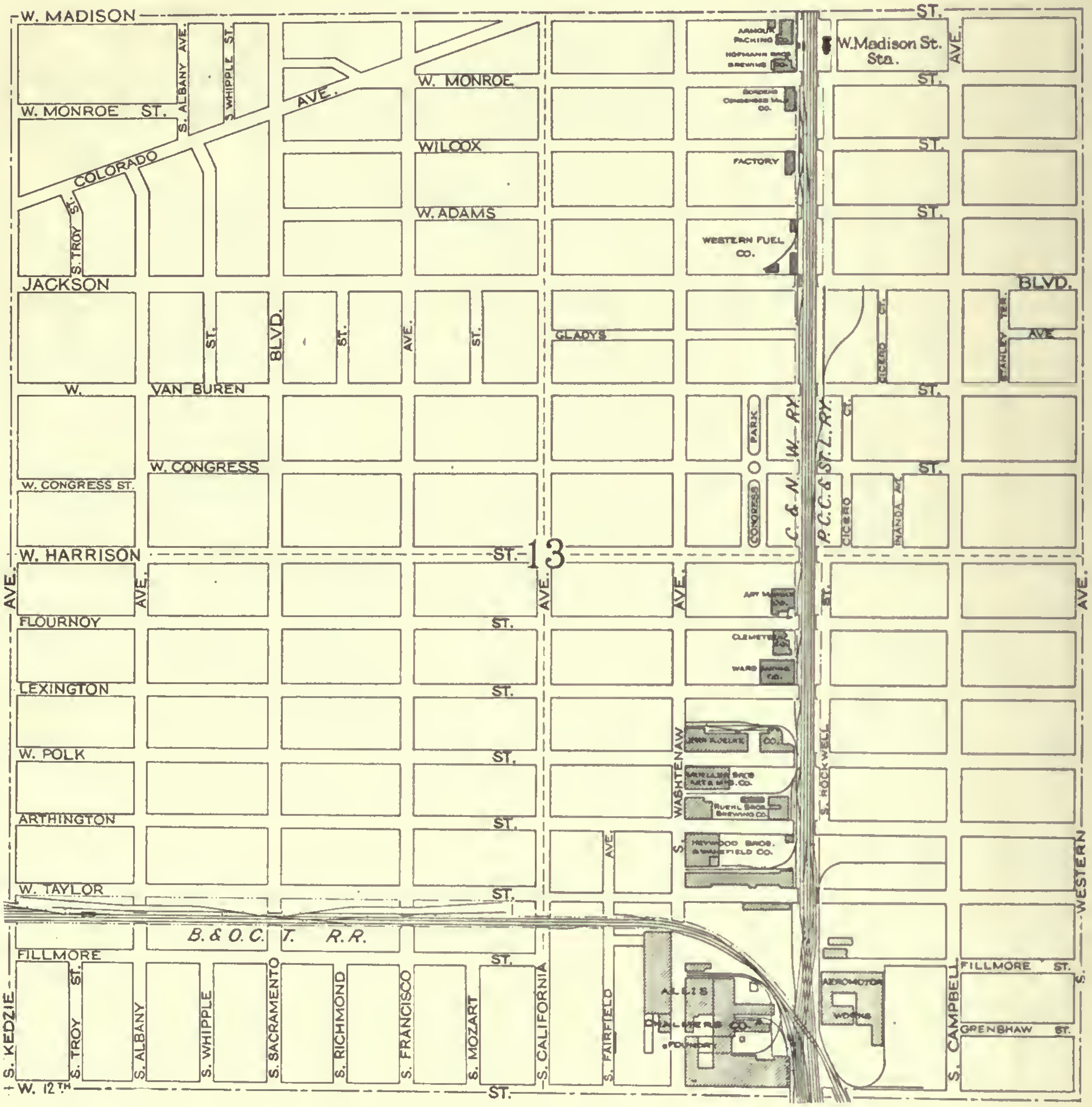

FIG. 129. SECTION MAP, INDEX NO. 35

Section 13 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

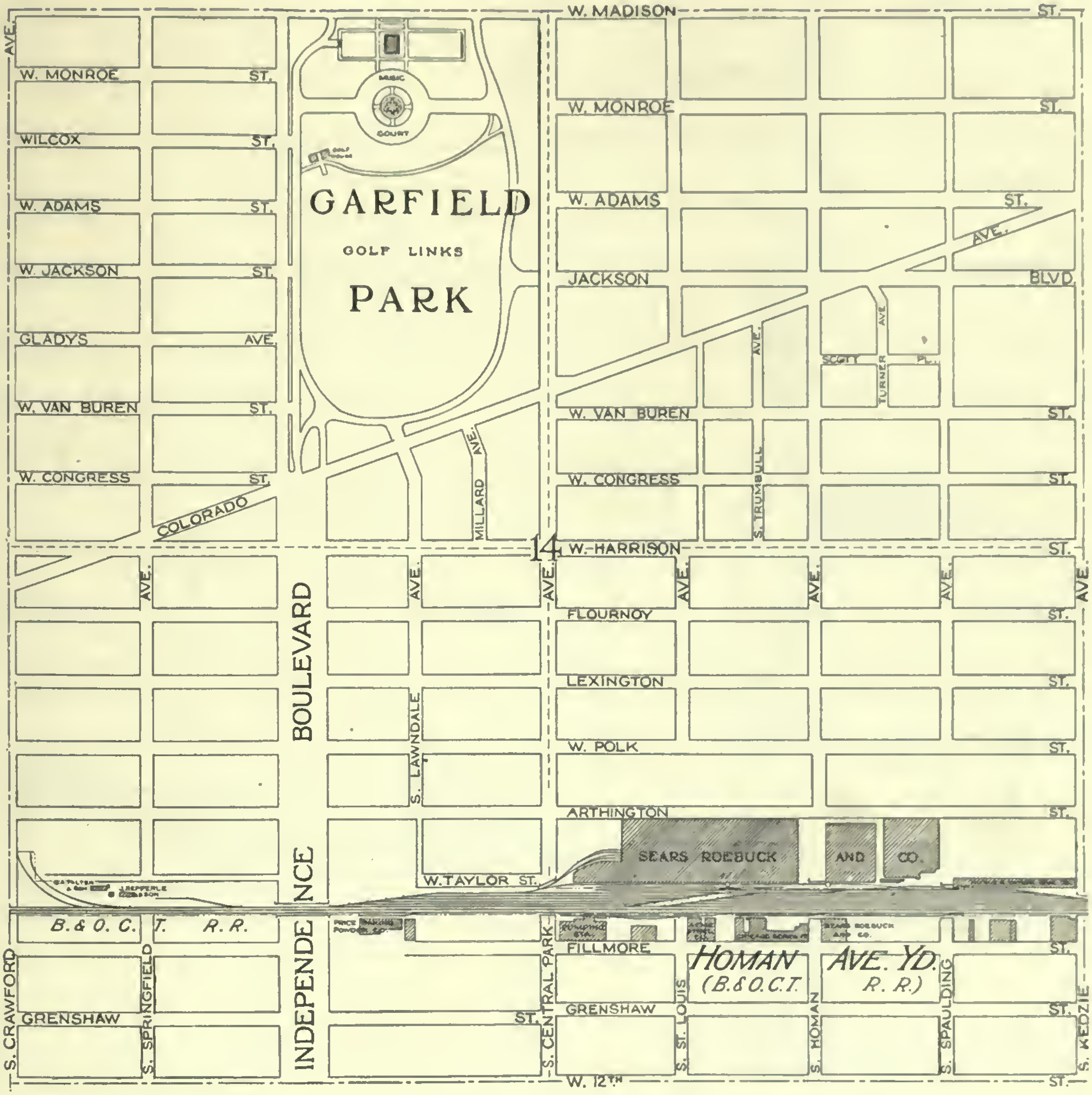

FIG. 130. SECTION MAP, INDEX NO. 36

Section 14 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

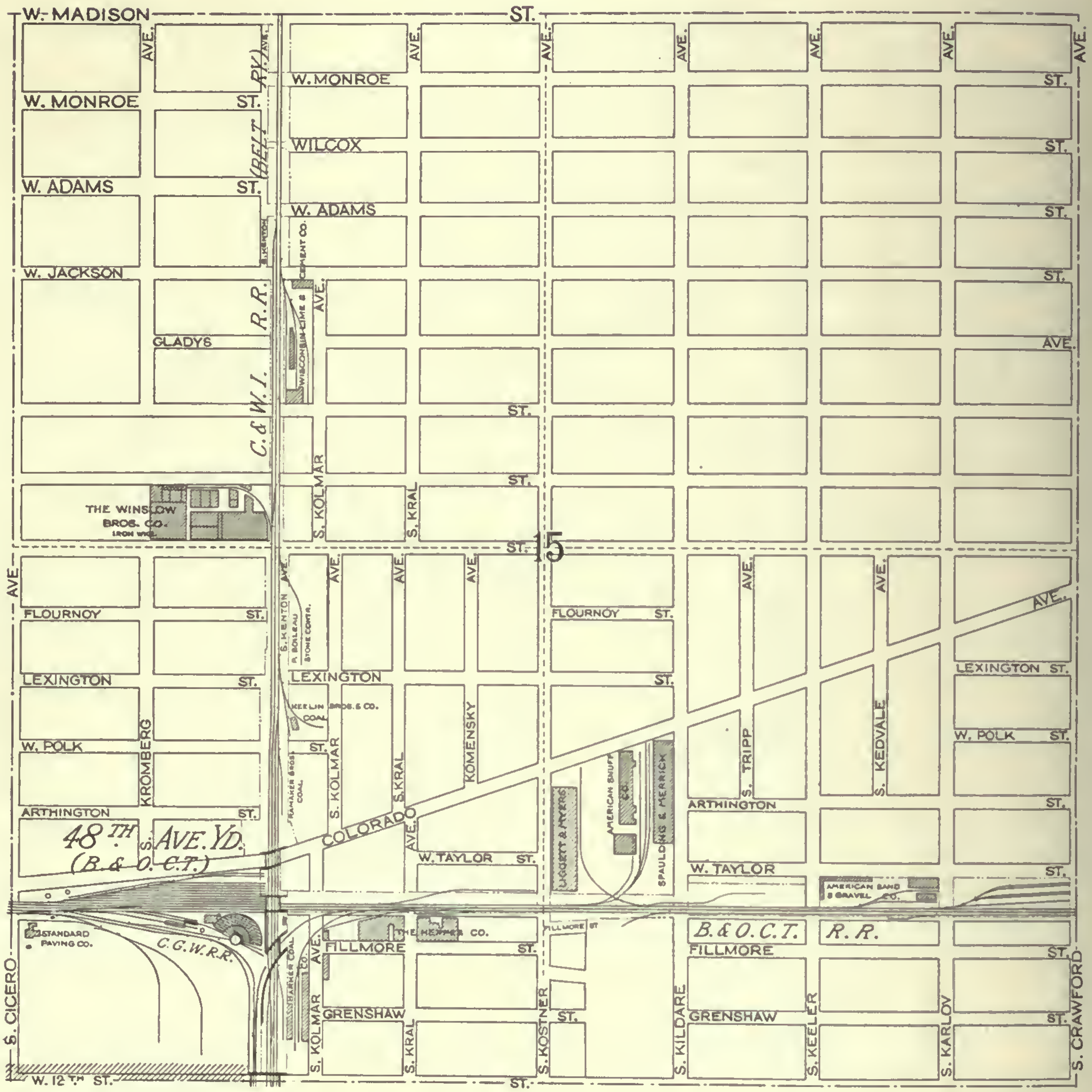

FIG. 131. SECTION MAP, INDEX NO. 37
Section 15 — Twp. 39 N. — R. 13. E. — 3 P. M. Scale: 1″ = 800′

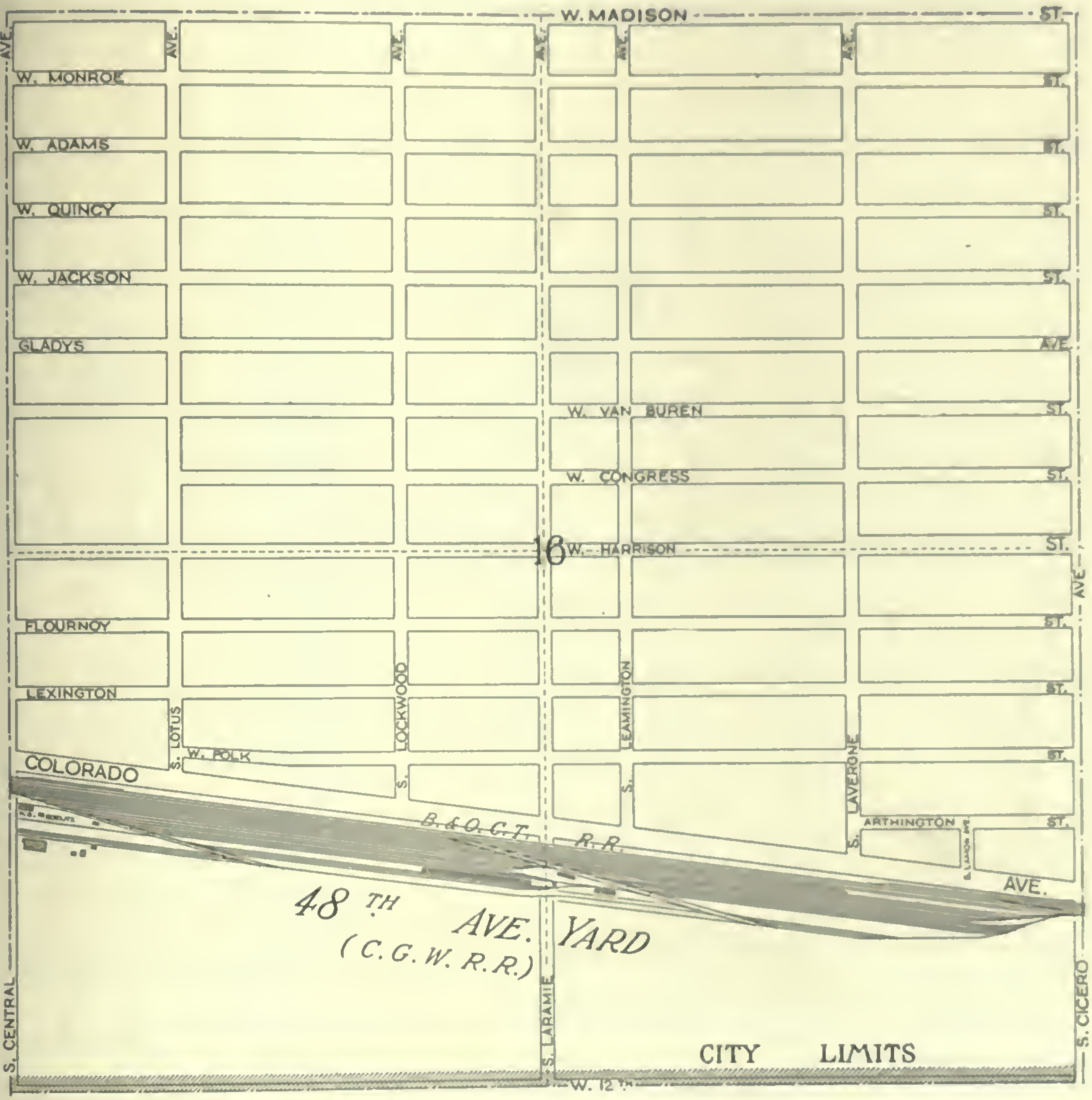

FIG. 132. SECTION MAP, INDEX NO. 38

Section 16 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

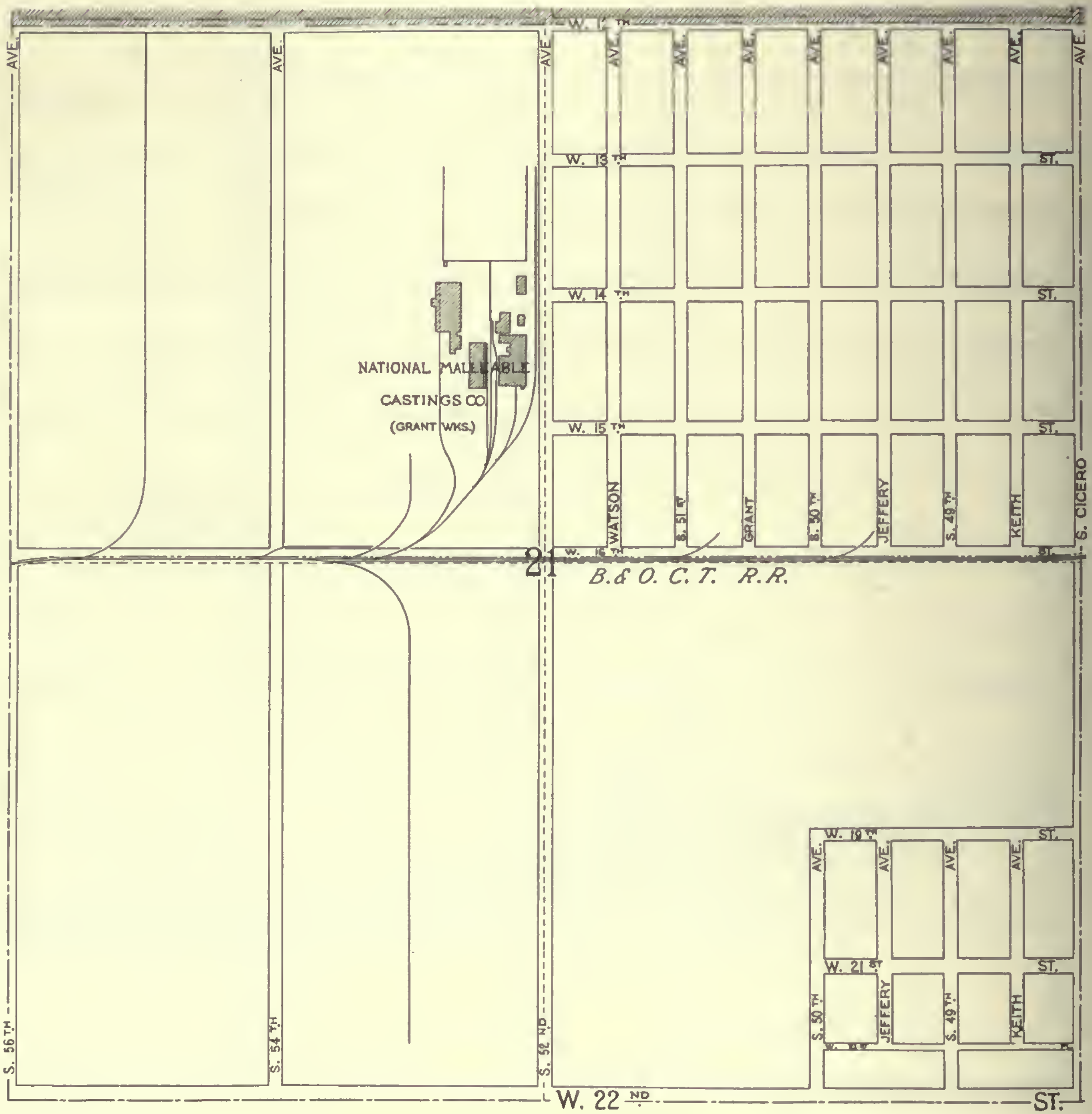

FIG. 133. SECTION MAP, INDEX NO. 39
Section 21 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

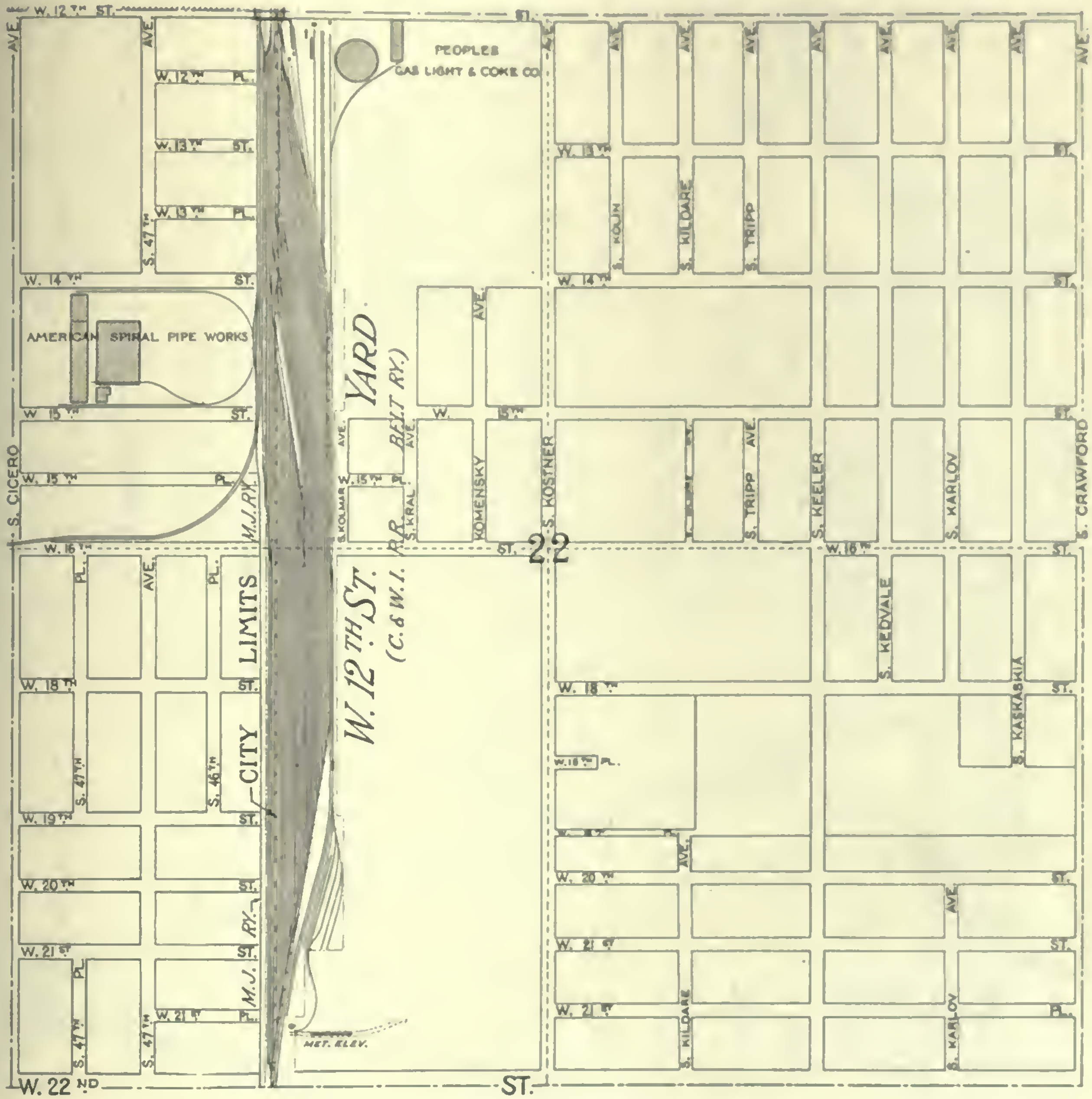

FIG. 134. SECTION MAP, INDEX NO. 40
Section 22 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

FIG. 135. SECTION MAP, INDEX NO. 41

Section 23 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″=800′

FIG. 136. SECTION MAP, INDEX NO. 42
Section 24 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

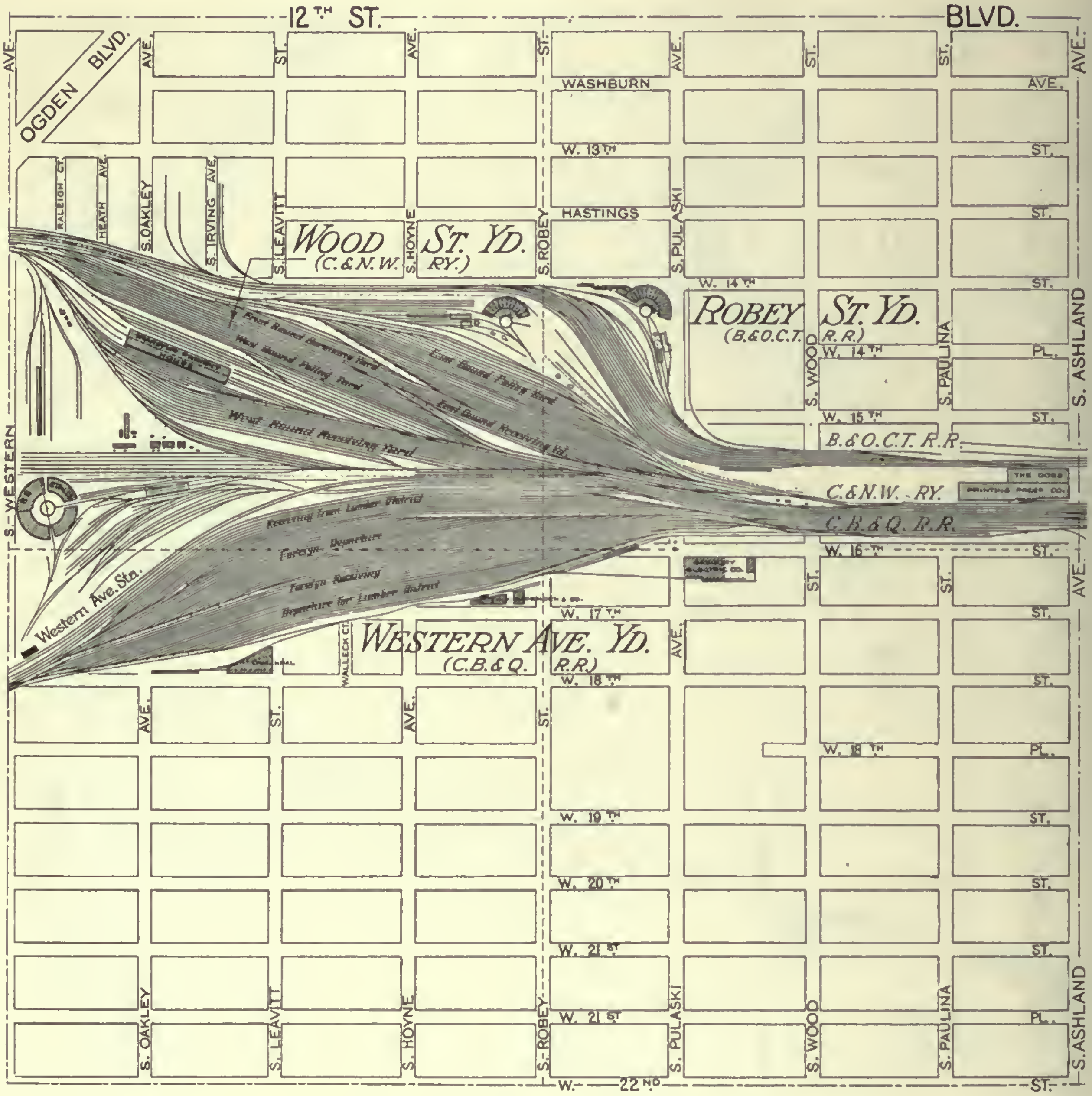

FIG. 137. SECTION MAP, INDEX NO. 43
Section 19—Twp. 39 N.—R. 14 E.—3 P. M. Scale: 1″=800′

FIG. 138. SECTION MAP, INDEX NO. 44

Section 20 — Twp. 39 N. — R. 14 E. — 3 P M. Scale: 1″ = 800′

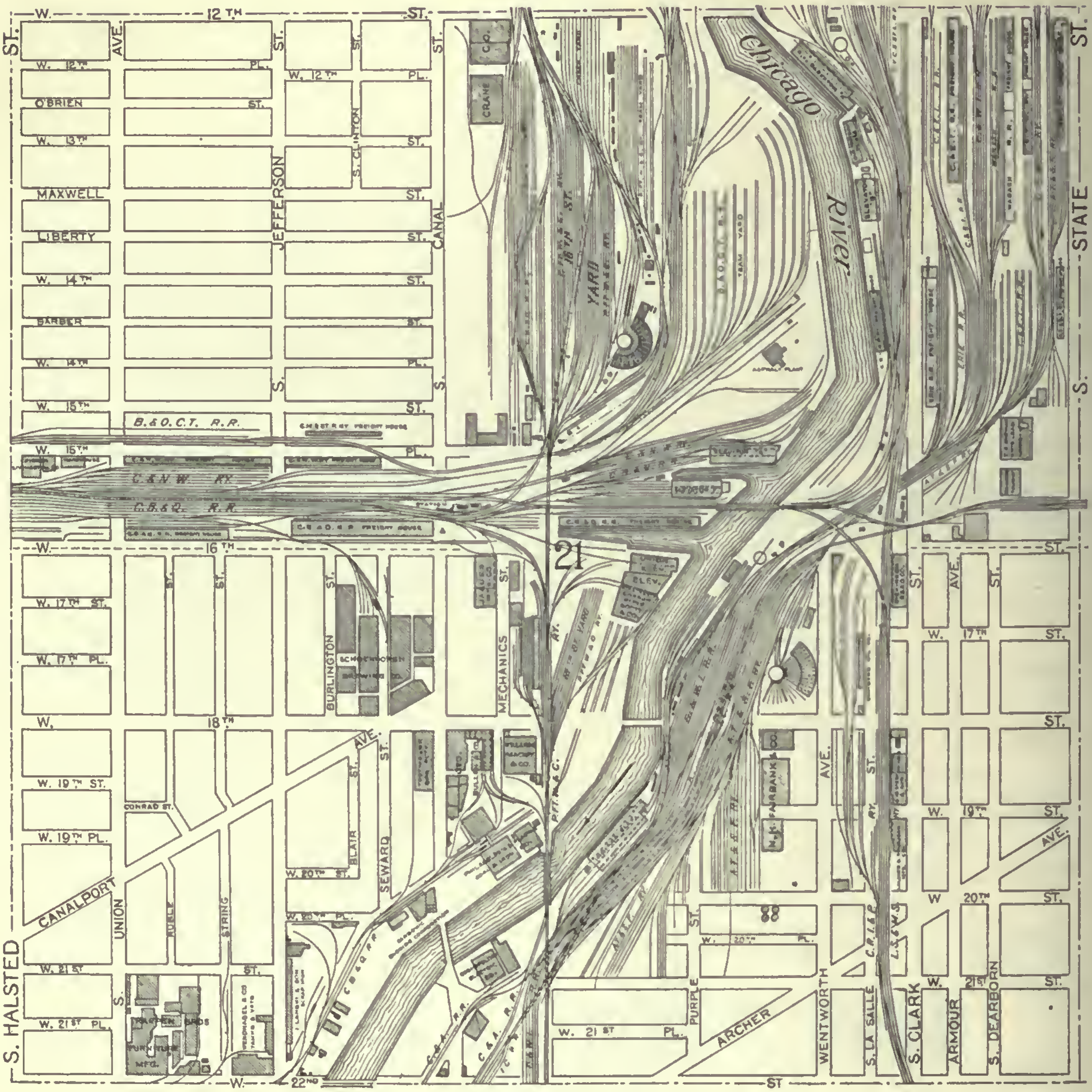

FIG. 139. SECTION MAP, INDEX NO. 45
Section 21 — Twp. 39 N.— R. 14 E.— 3 P. M. Scale: 1″=800′

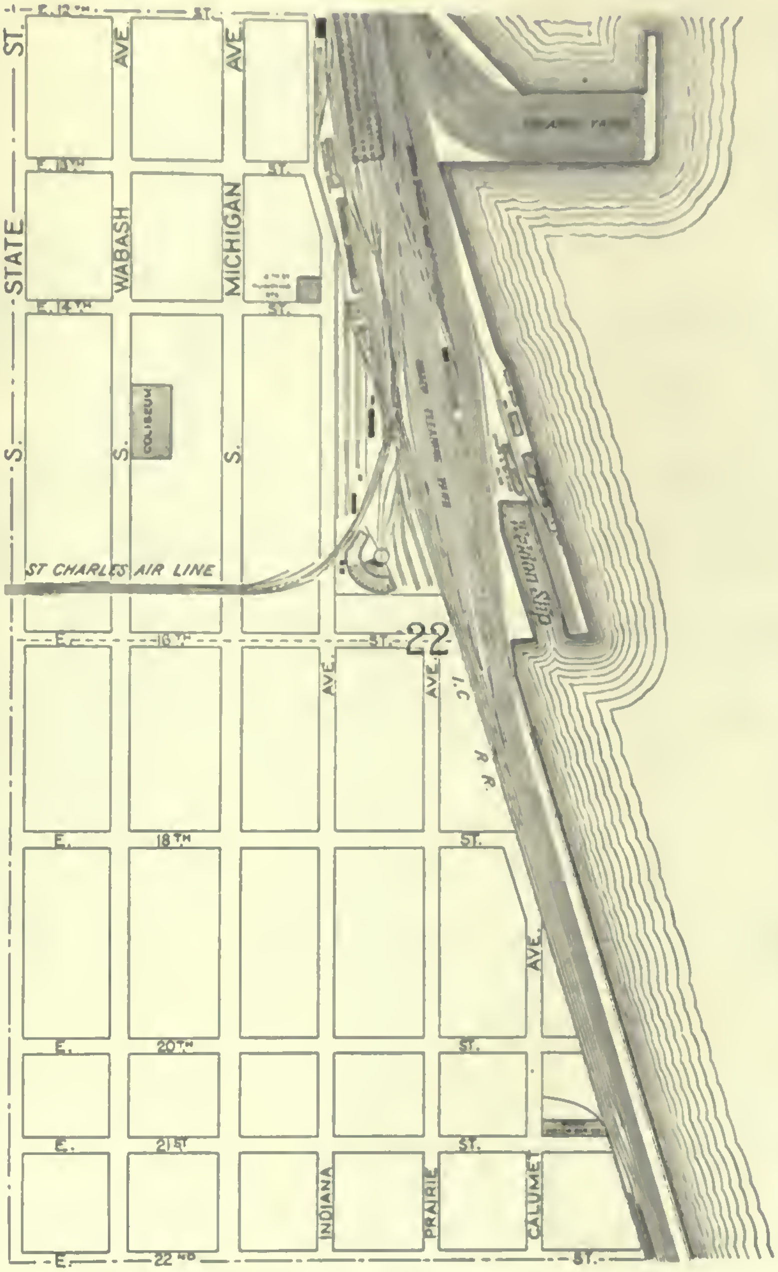

FIG. 140. SECTION MAP, INDEX NO. 46

Fractional Section 22 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

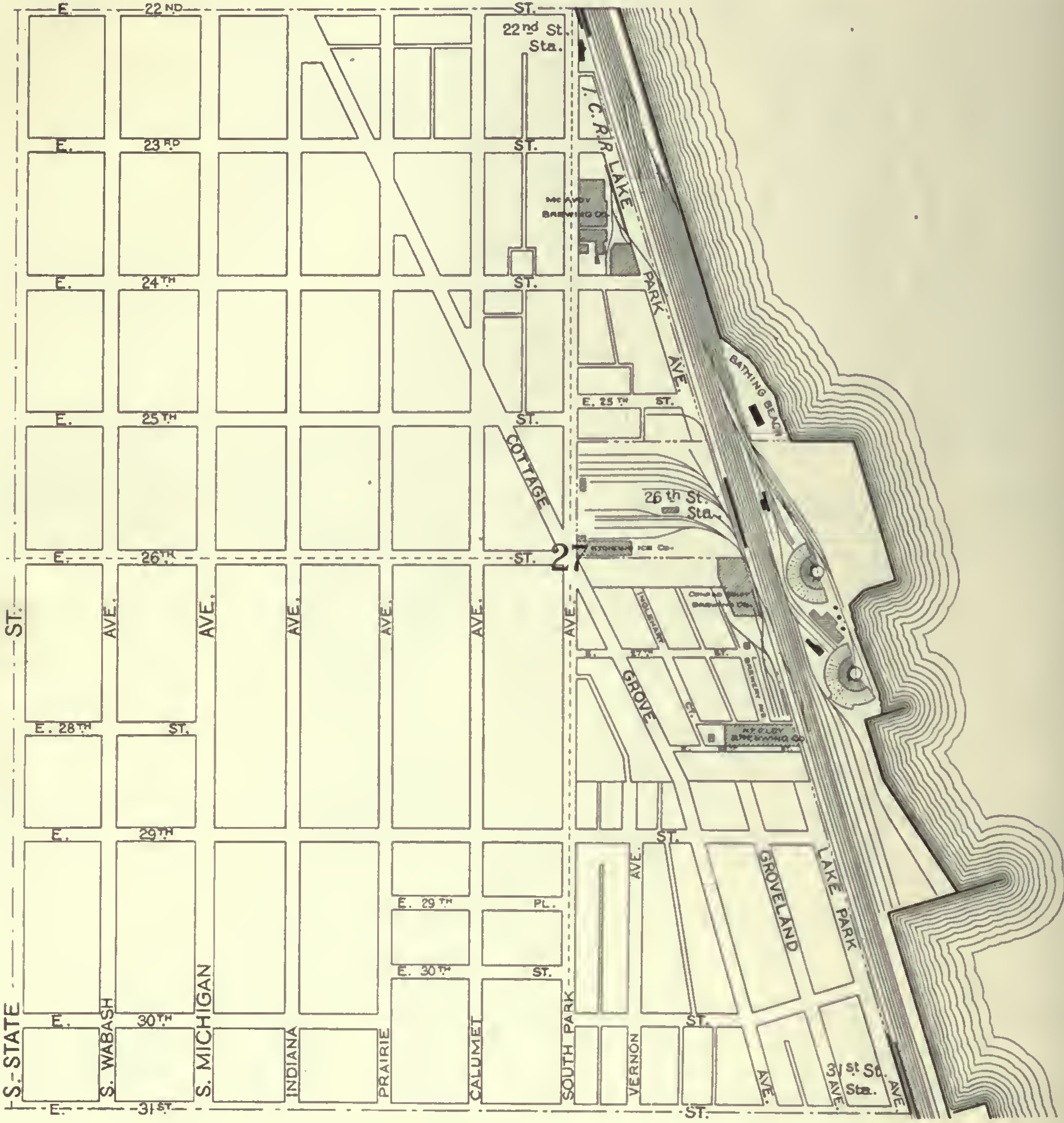

FIG. 141. SECTION MAP, INDEX NO. 47

Fractional Section 27 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

FIG. 142. SECTION MAP, INDEX NO. 48

Section 28 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1" = 800'

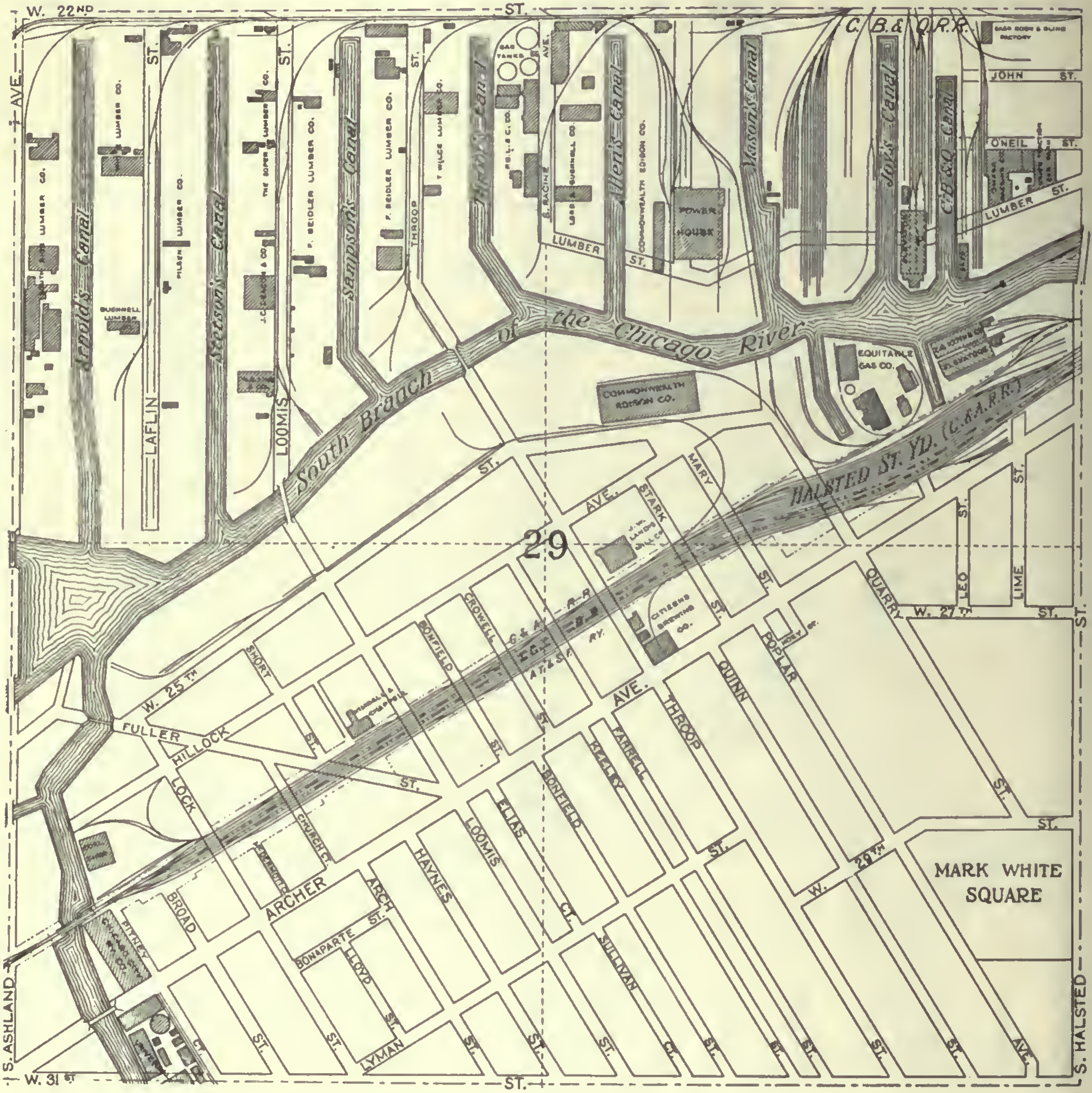

FIG. 143. SECTION MAP, INDEX NO. 49
Section 29 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

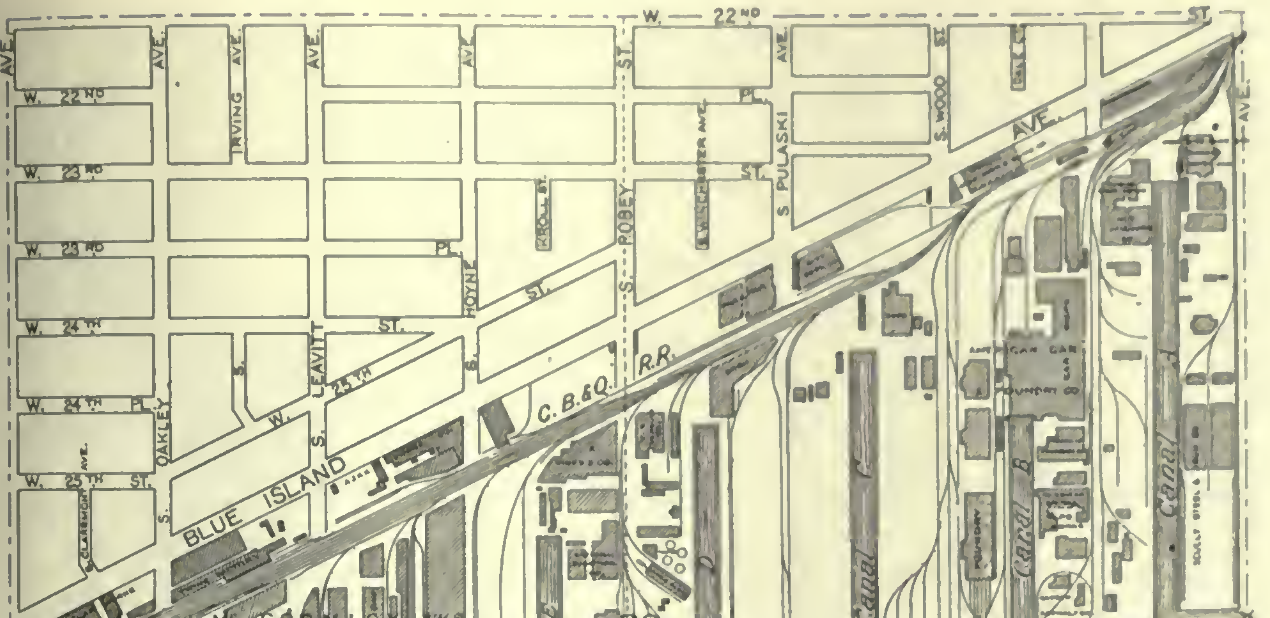

FIG. 144. SECTION MAP, INDEX NO. 50

Section 30 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

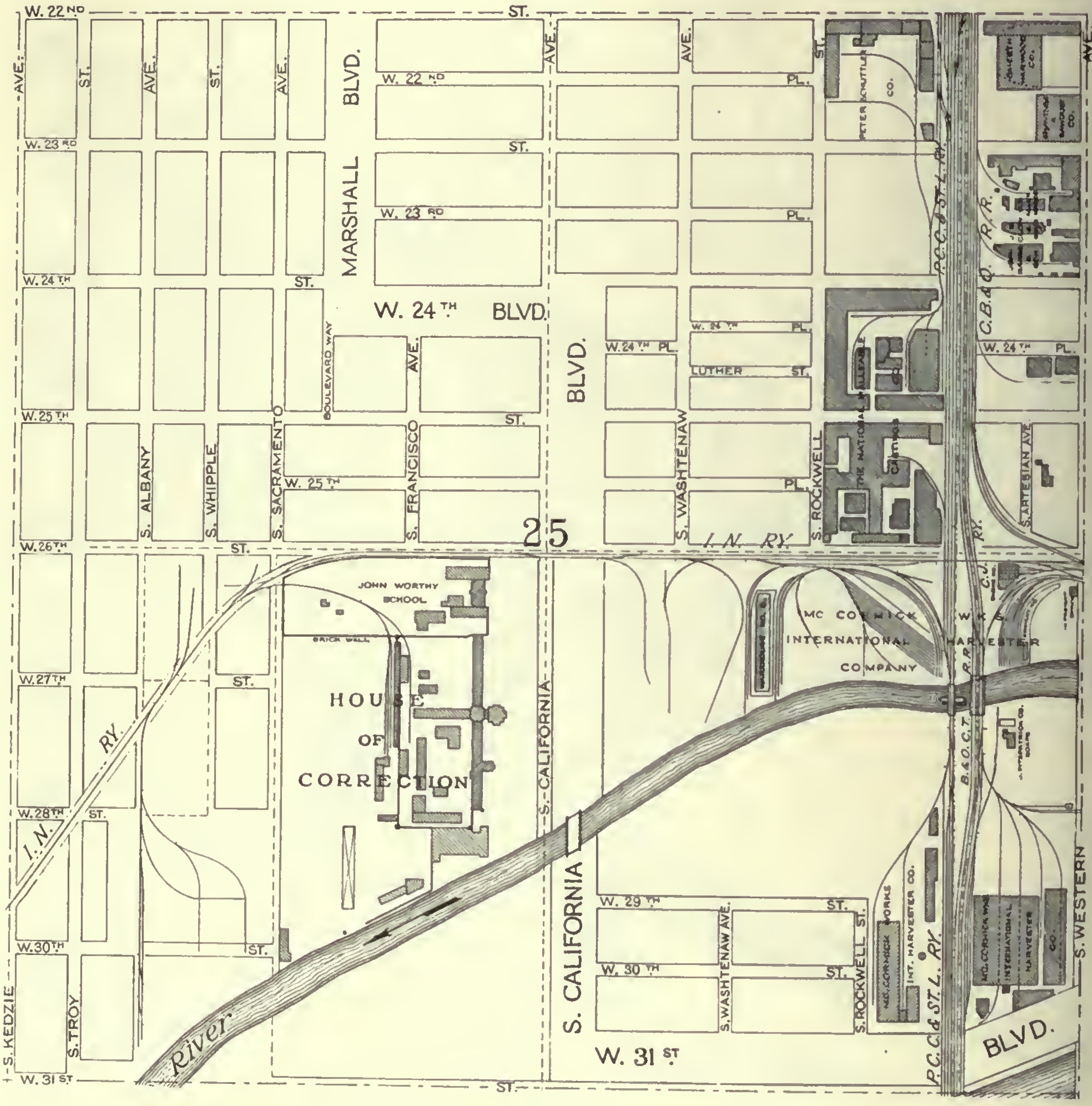

FIG. 145. SECTION MAP, INDEX NO. 51

Section 25 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

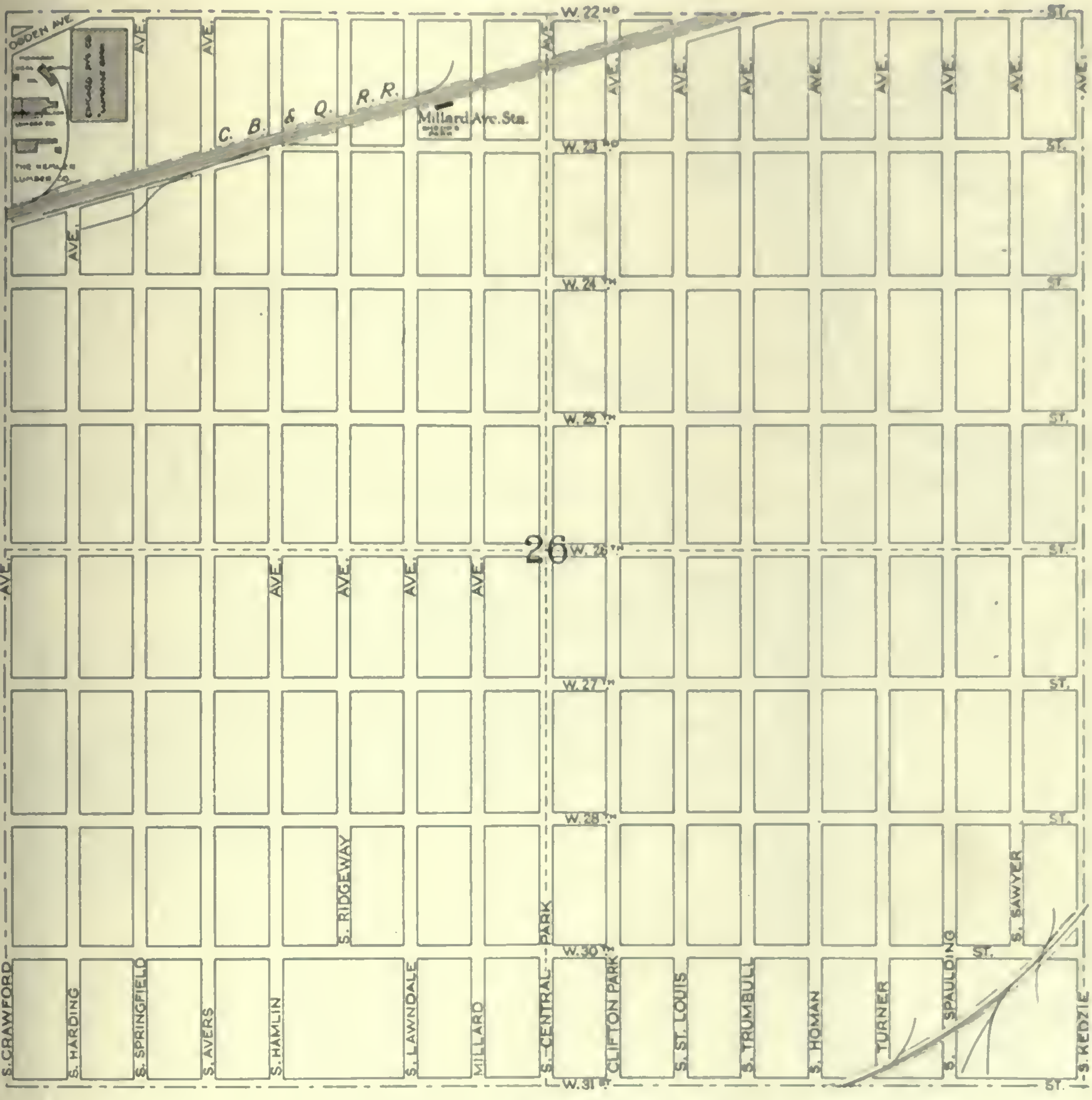

FIG. 146. SECTION MAP, INDEX NO. 52
Section 26 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

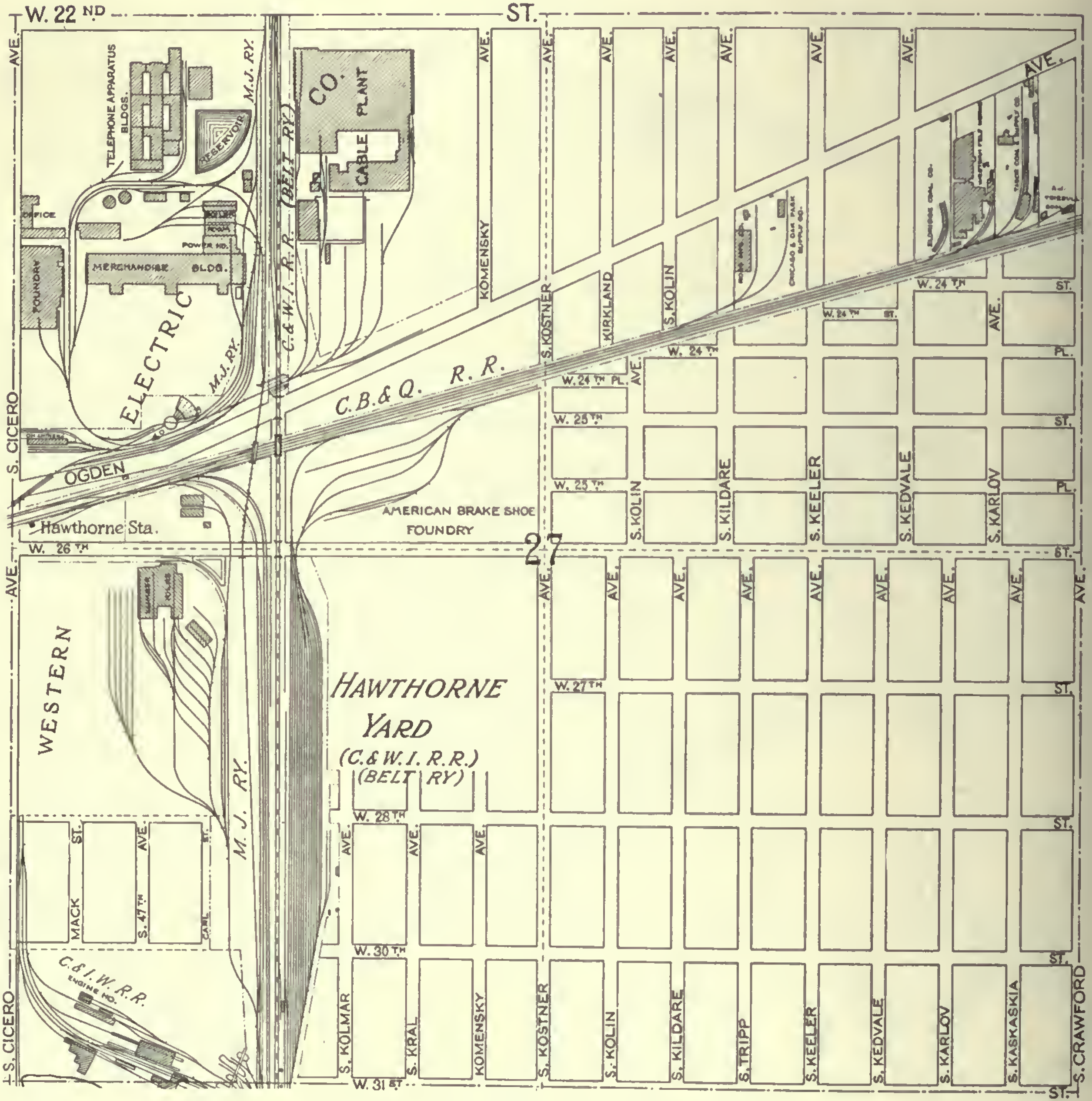

FIG. 147. SECTION MAP, INDEX NO. 53

Section 27—Twp. 39 N.—R. 13 E.—3 P. M. Scale: 1″=800′

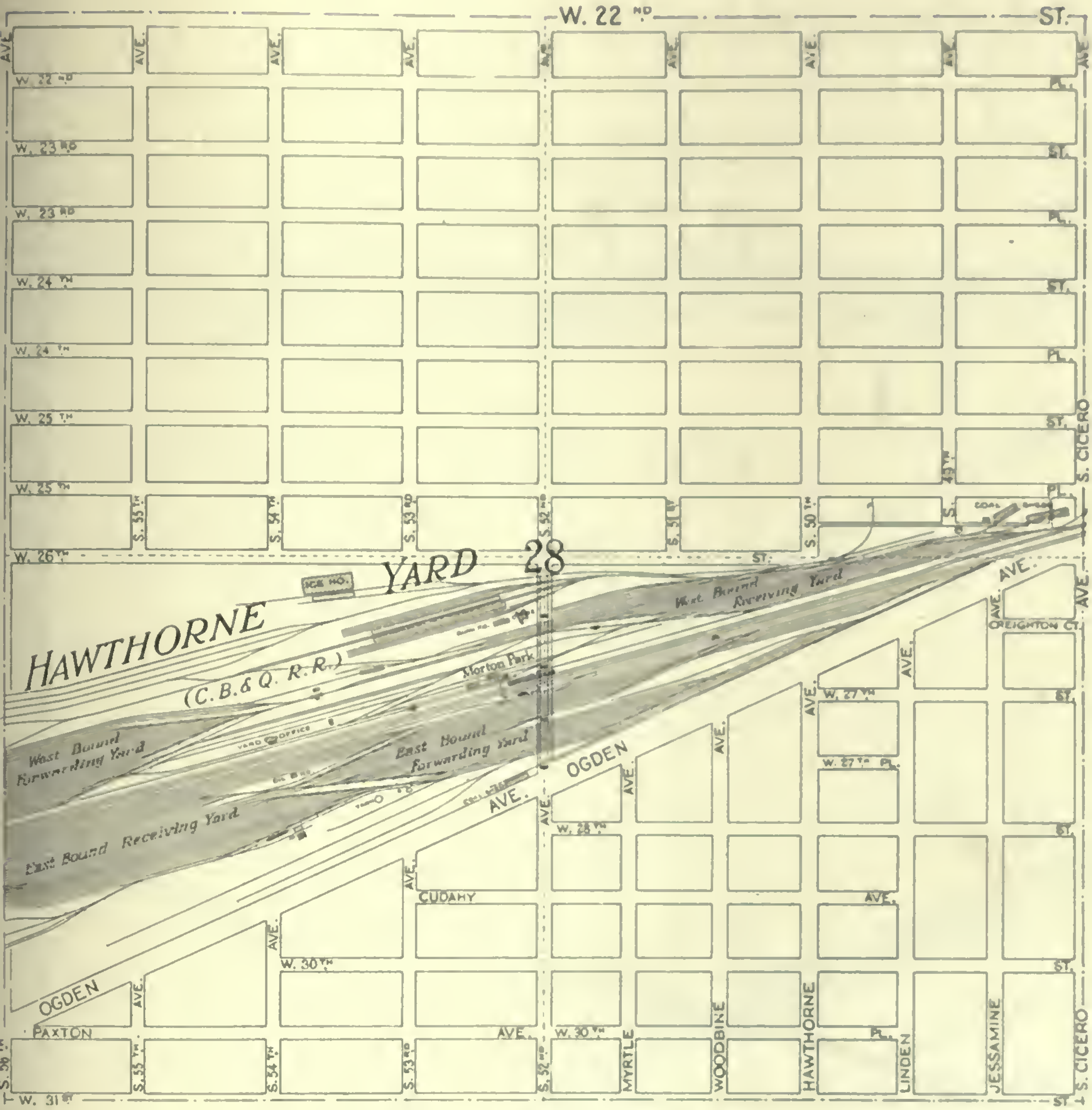

FIG. 148. SECTION MAP, INDEX NO. 54
Section 28 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

FIG. 149. SECTION MAP, INDEX NO. 55

Section 33 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

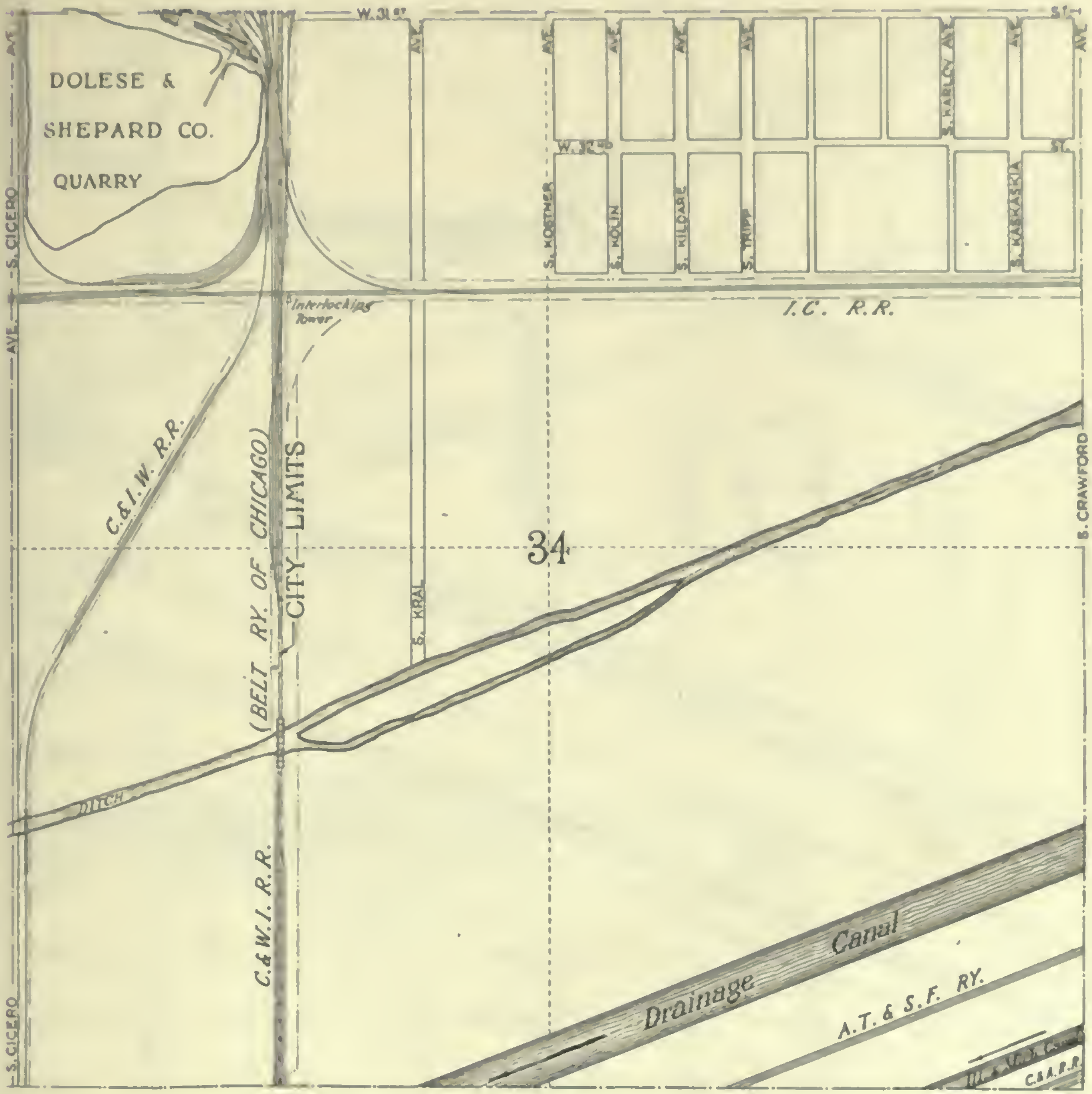

FIG. 150. SECTION MAP, INDEX NO. 56
Section 34 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

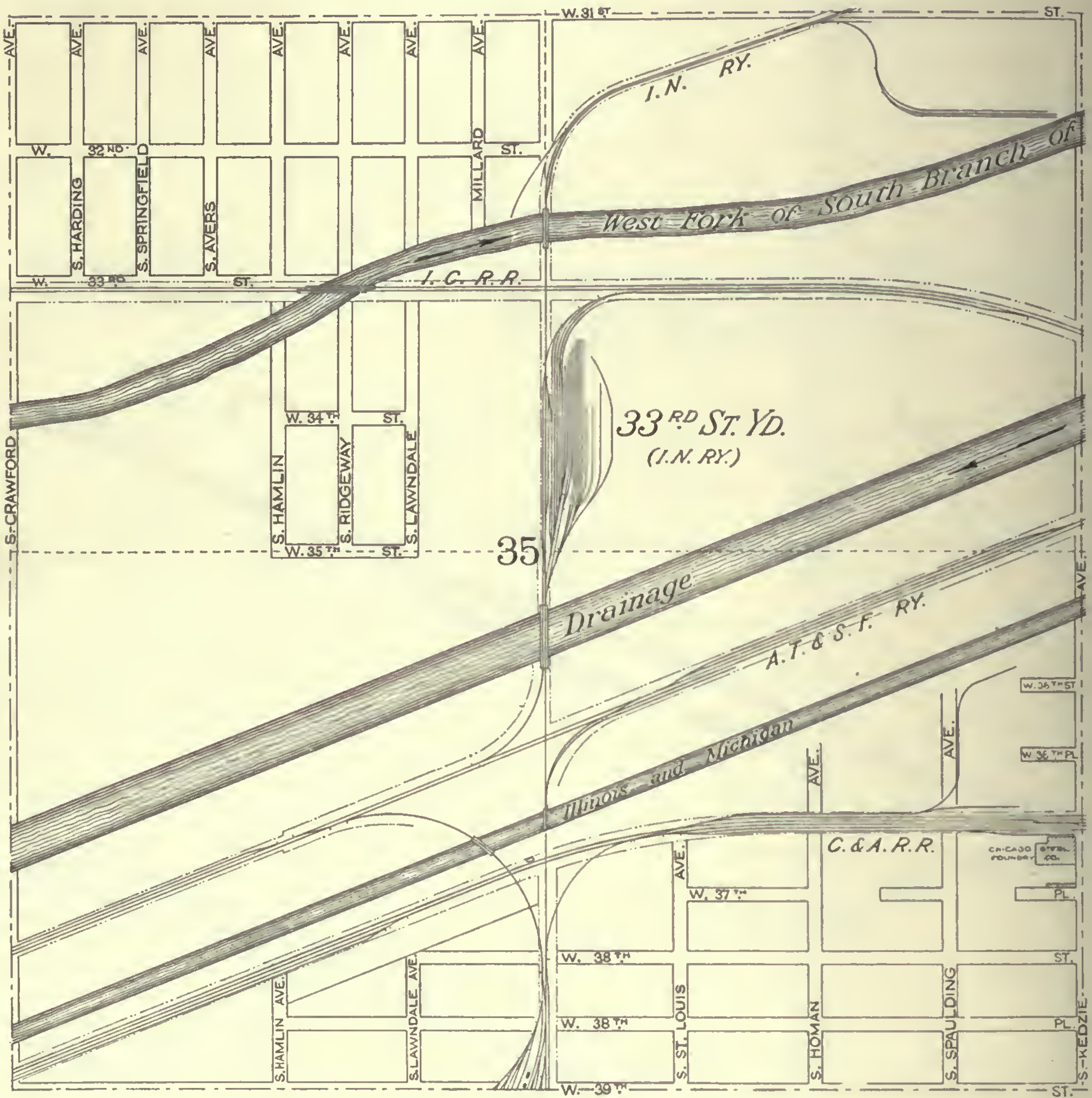

FIG. 151. SECTION MAP, INDEX NO. 57

Section 35 —Twp. 39 N.— R. 13 E.— 3 P. M. Scale: 1″ = 800′

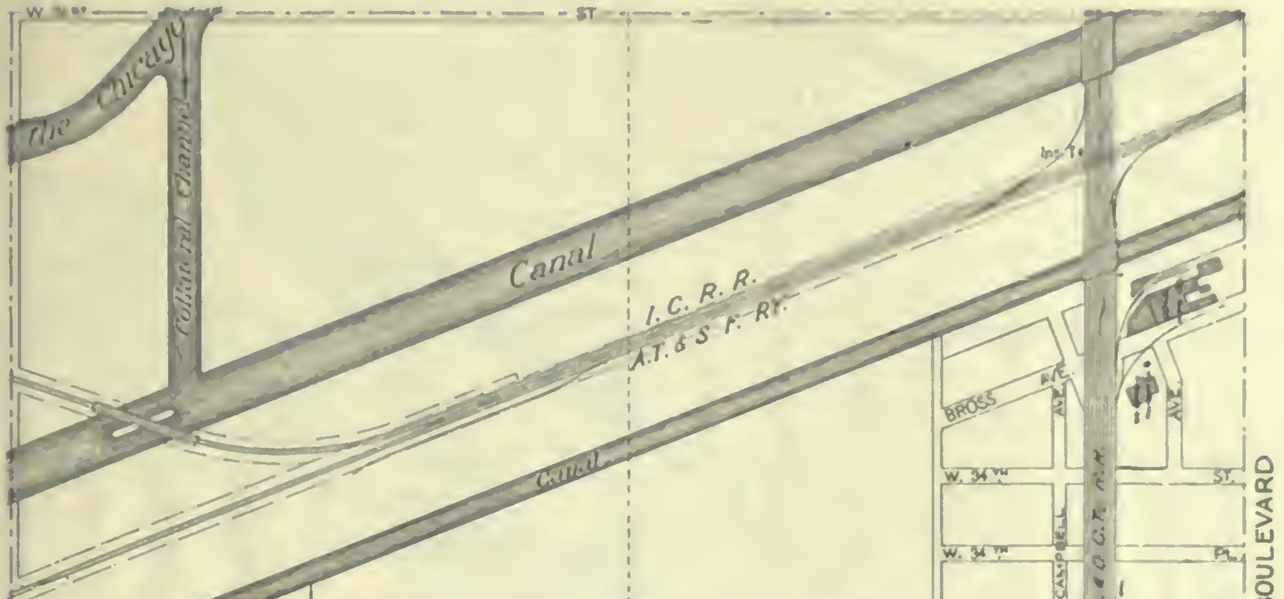

FIG. 152. SECTION MAP, INDEX NO. 58
Section 36 — Twp. 39 N. — R. 13 E. — 3 P. M. Scale: 1" = 800'

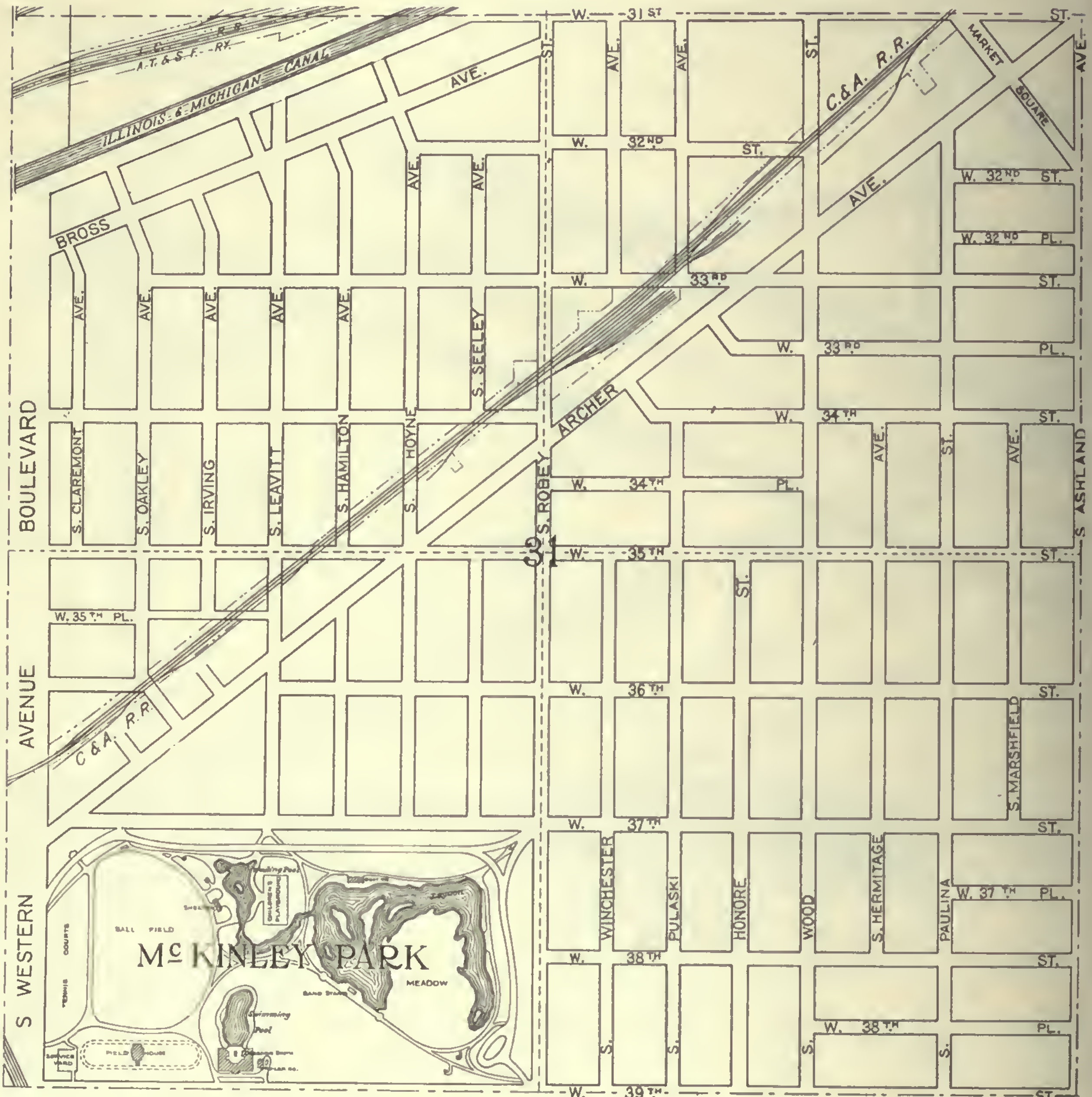

FIG. 153. SECTION MAP, INDEX NO. 59

Section 31 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

FIG. 154. SECTION MAP, INDEX NO. 60

Section 32 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

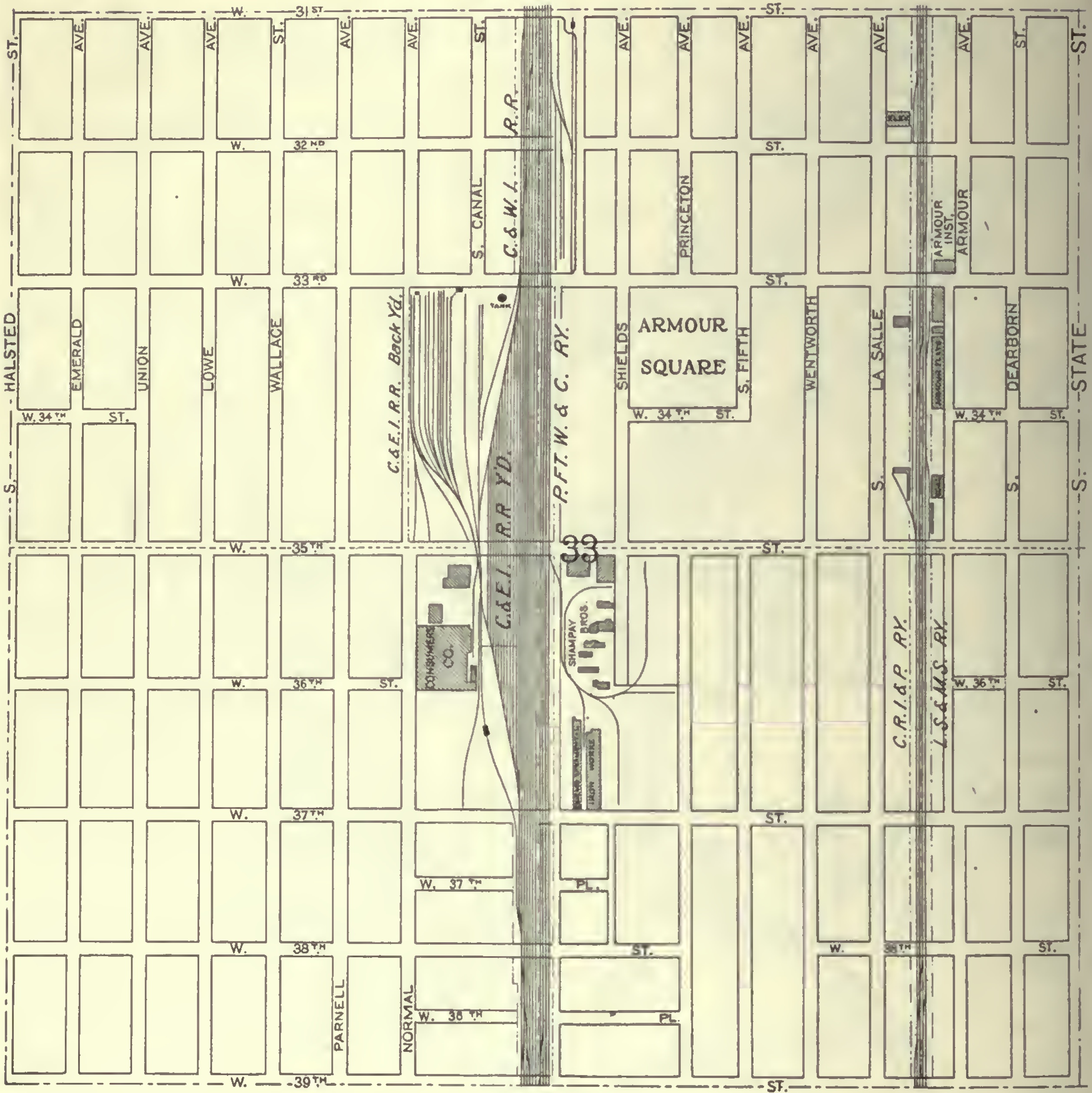

FIG. 155. SECTION MAP, INDEX NO. 61
Section 33 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1″=800′

FIG. 156. SECTION MAP, INDEX NO. 62

Fractional Section 34 — Twp. 39 N. — R. 14 E. — 3 P. M. Scale: 1" = 800'

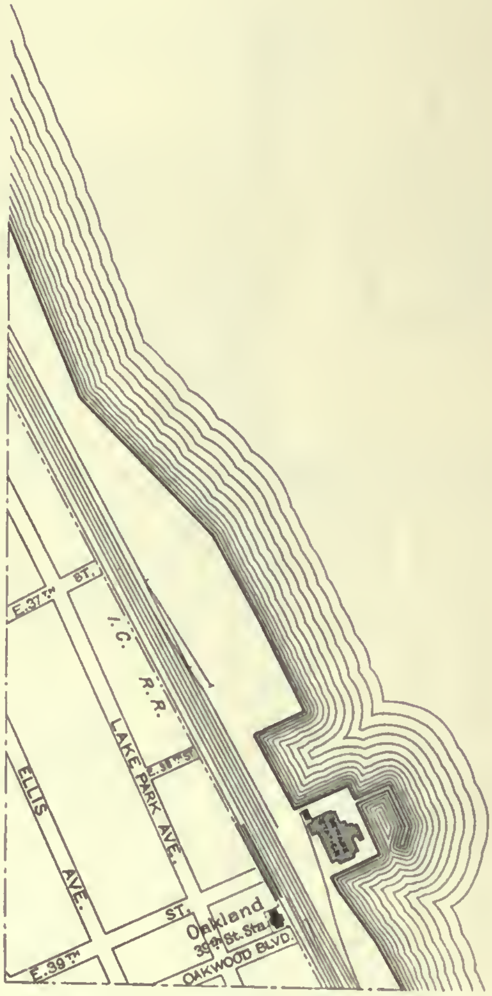

FIG. 157. SECTION MAP, INDEX NO. 63
Fractional Section 35 — Twp. 39 N. — R. 14 E. Scale: 1″ = 800′

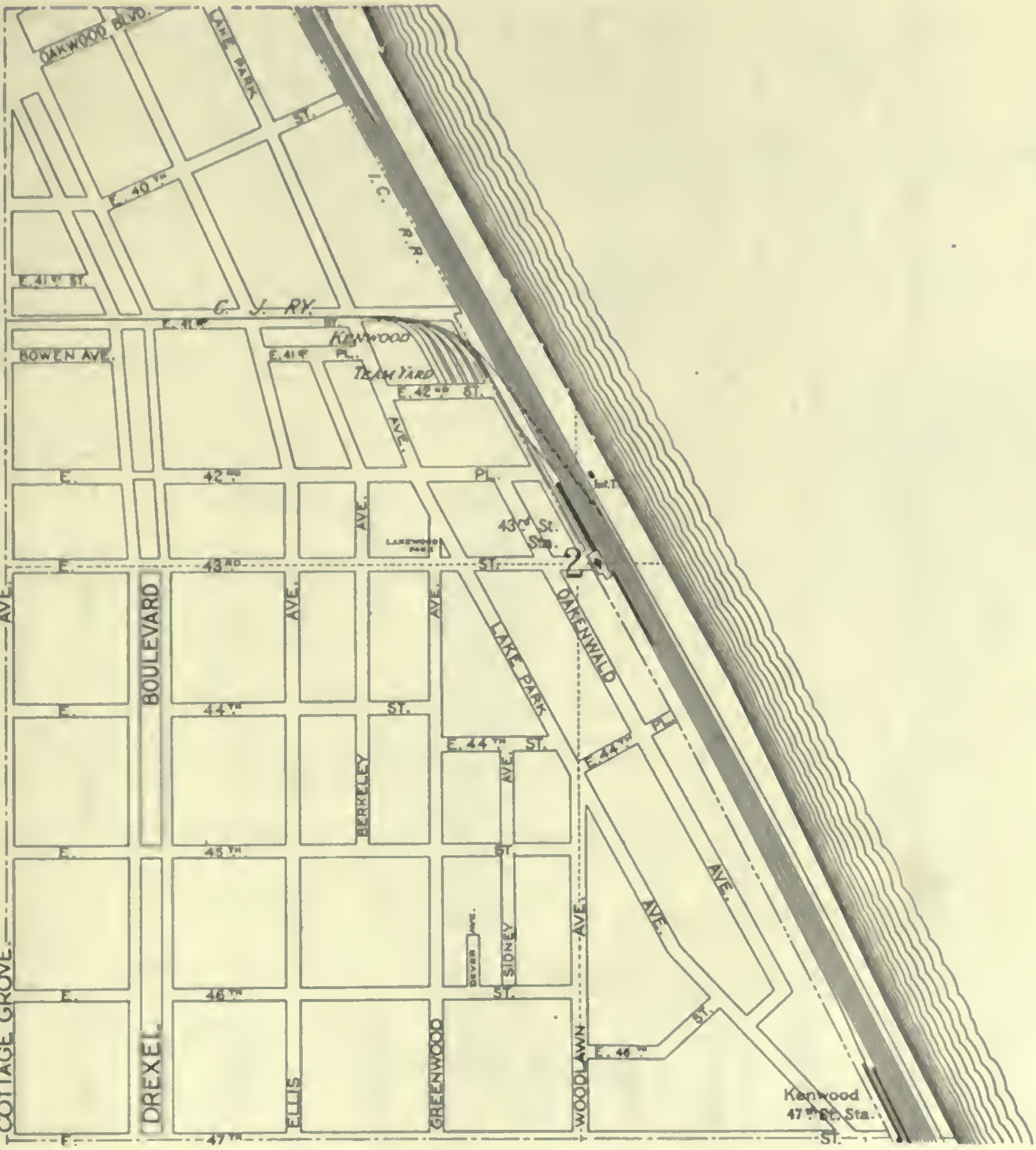

FIG. 158. SECTION MAP, INDEX NO. 64

Fractional Section 2 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

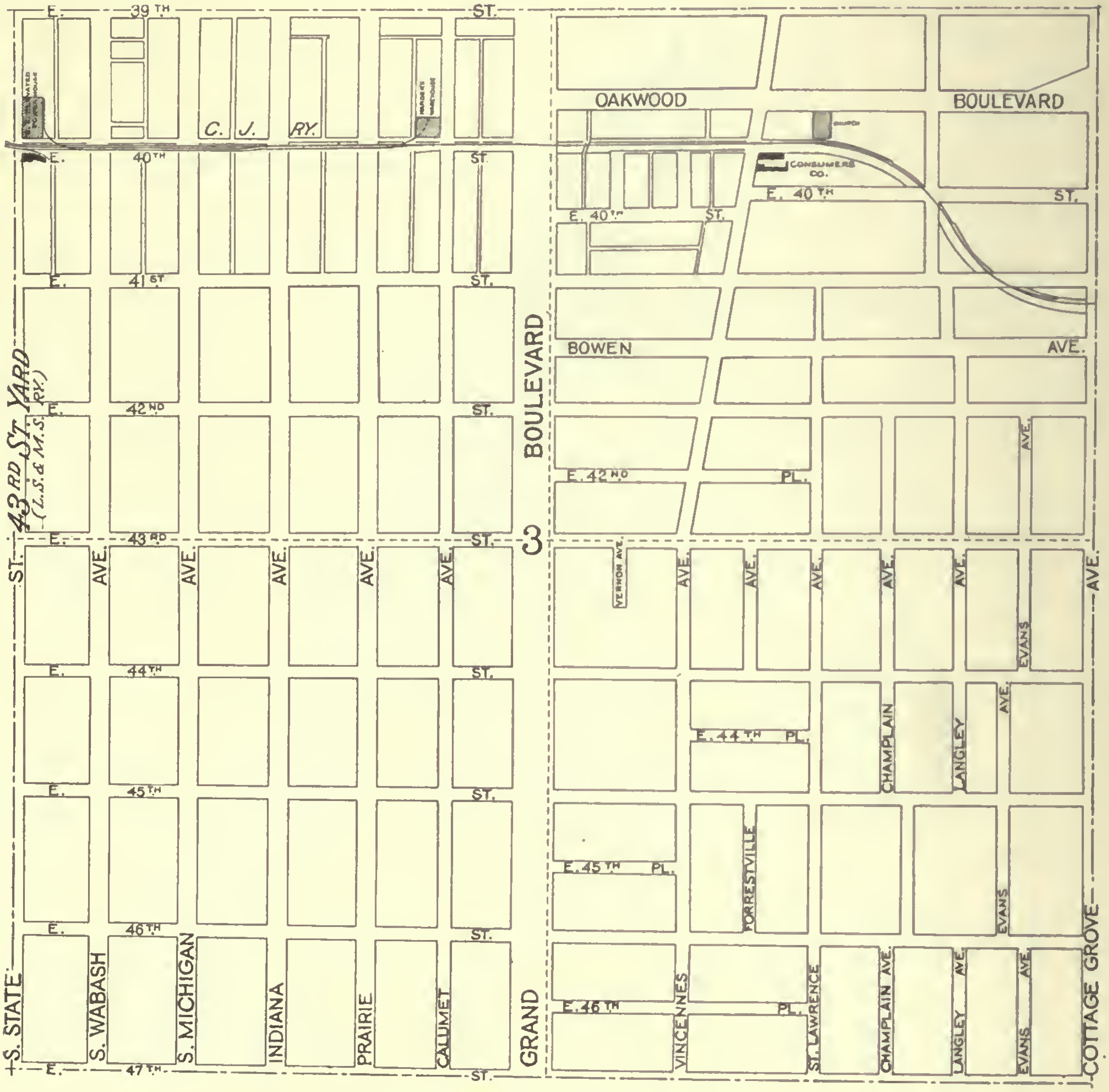

FIG. 159. SECTION MAP, INDEX NO. 65

Section 3 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

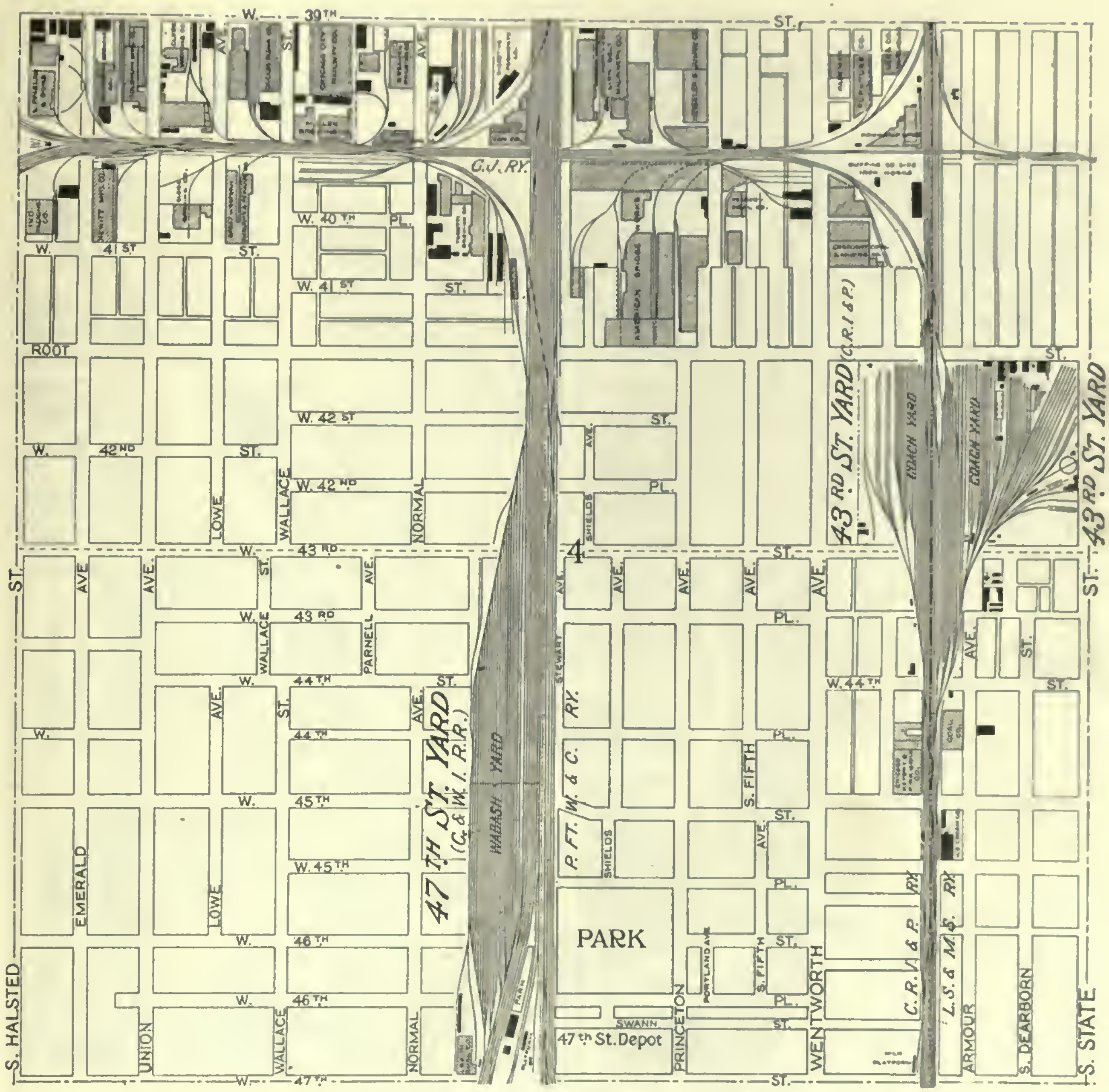

FIG. 160. SECTION MAP, INDEX NO. 66

Section 4 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

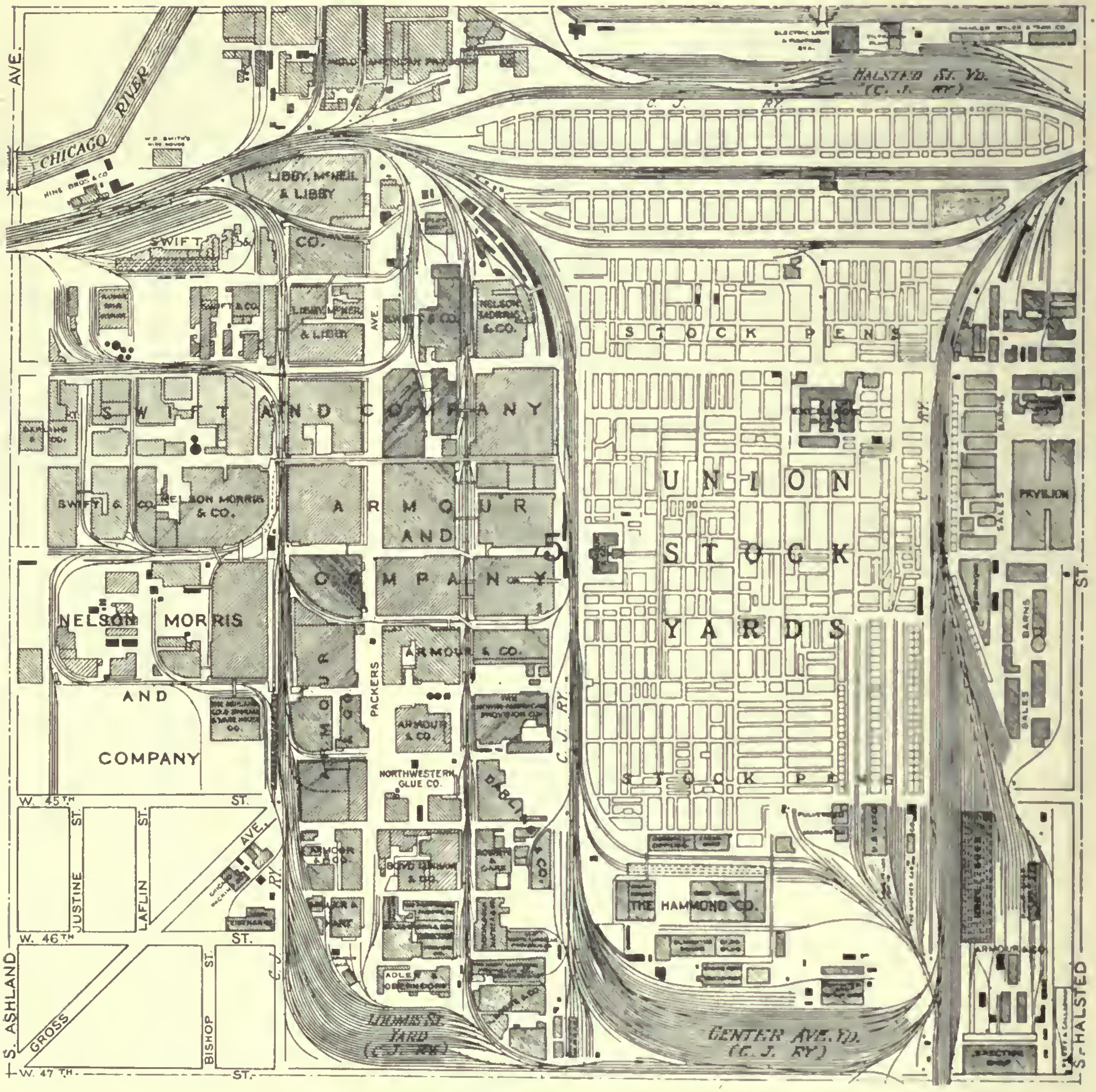

FIG. 161. SECTION MAP, INDEX NO. 67

Section 5 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

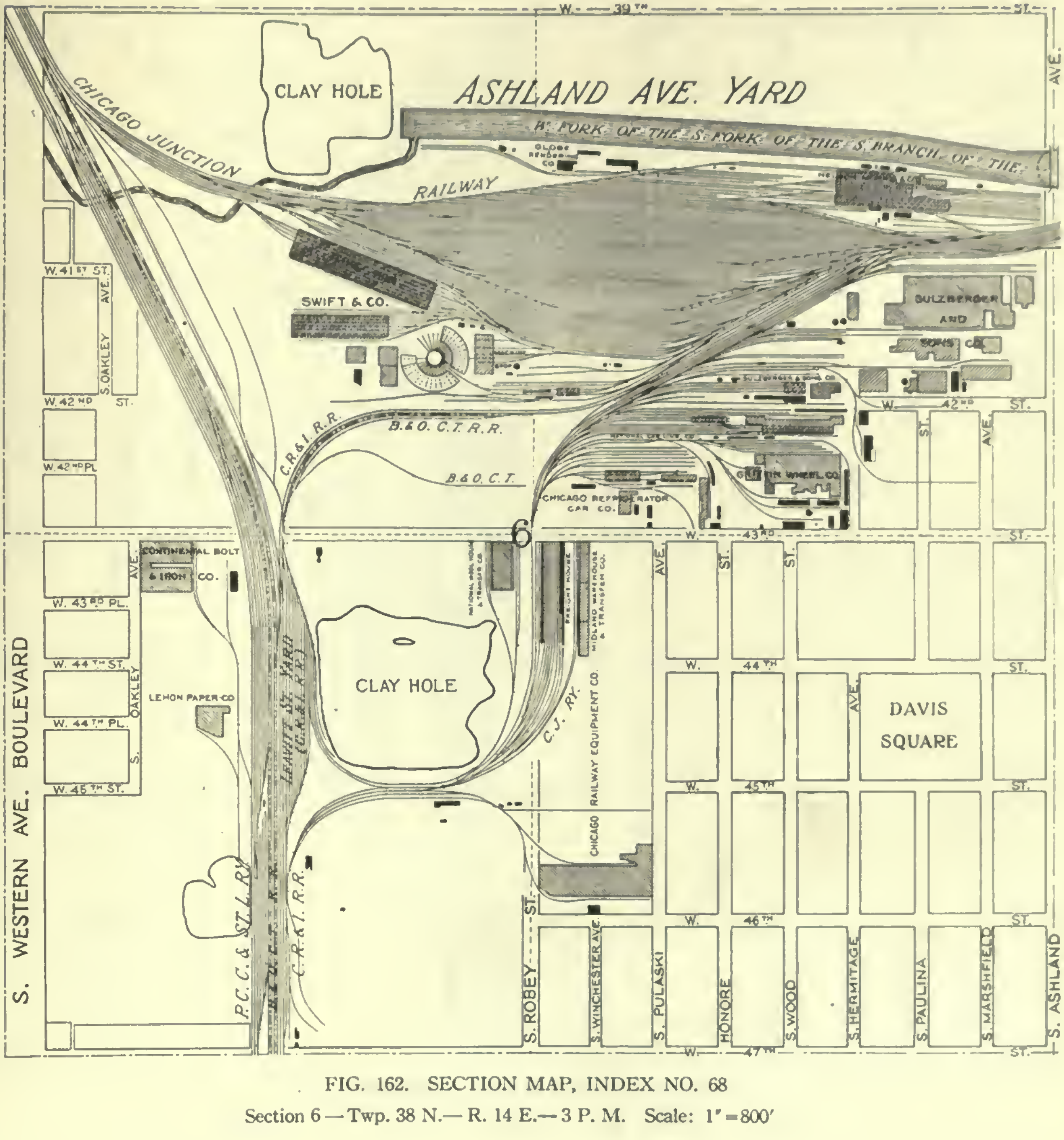

FIG. 162. SECTION MAP, INDEX NO. 68

Section 6 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

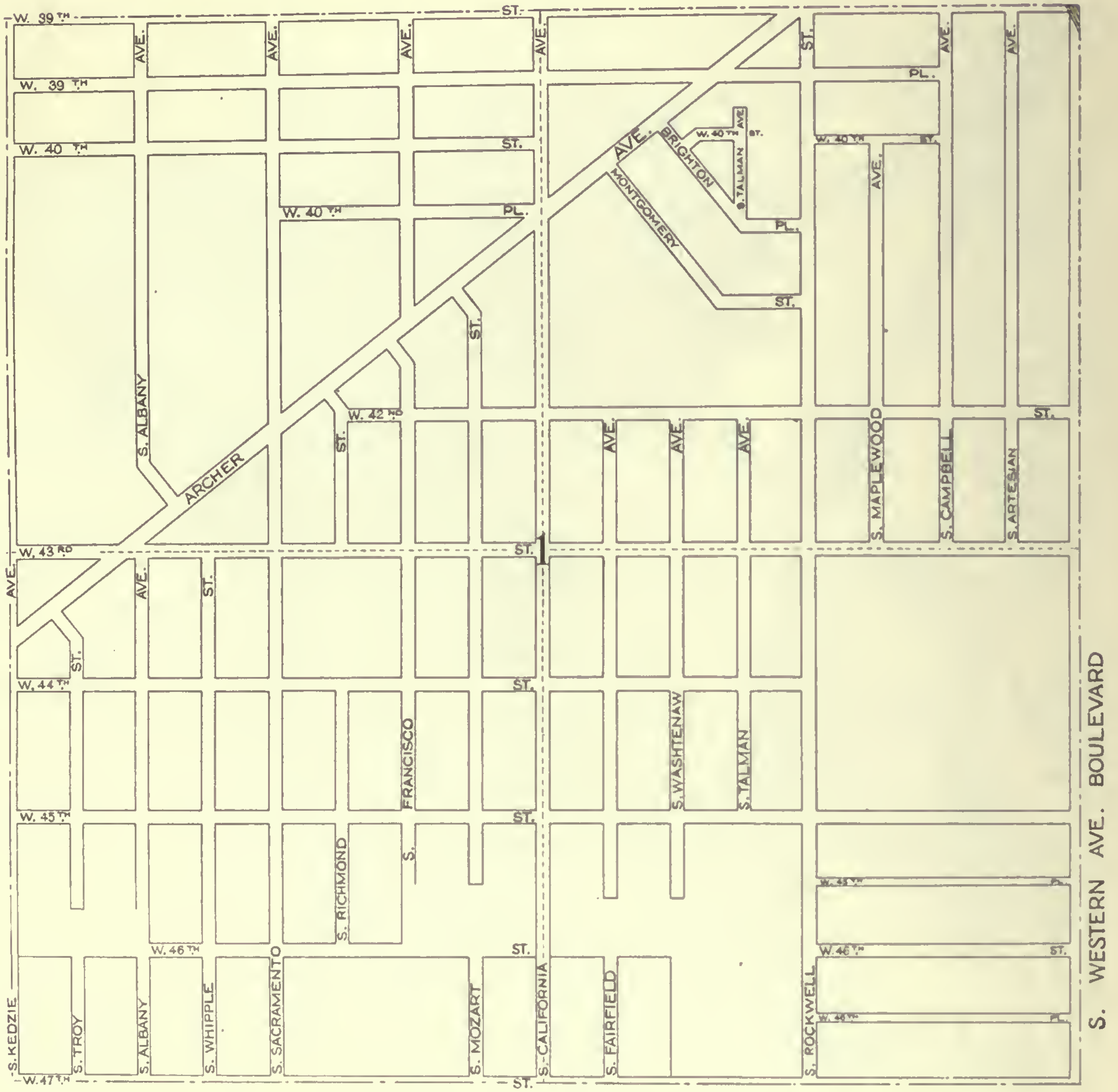

FIG. 163. SECTION MAP, INDEX NO. 69

Section 1 — Twp. 38 N.— R. 13 E.— 3 P. M. Scale: 1″ = 800′

FIG. 164. SECTION MAP, INDEX NO. 70

Section 2 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

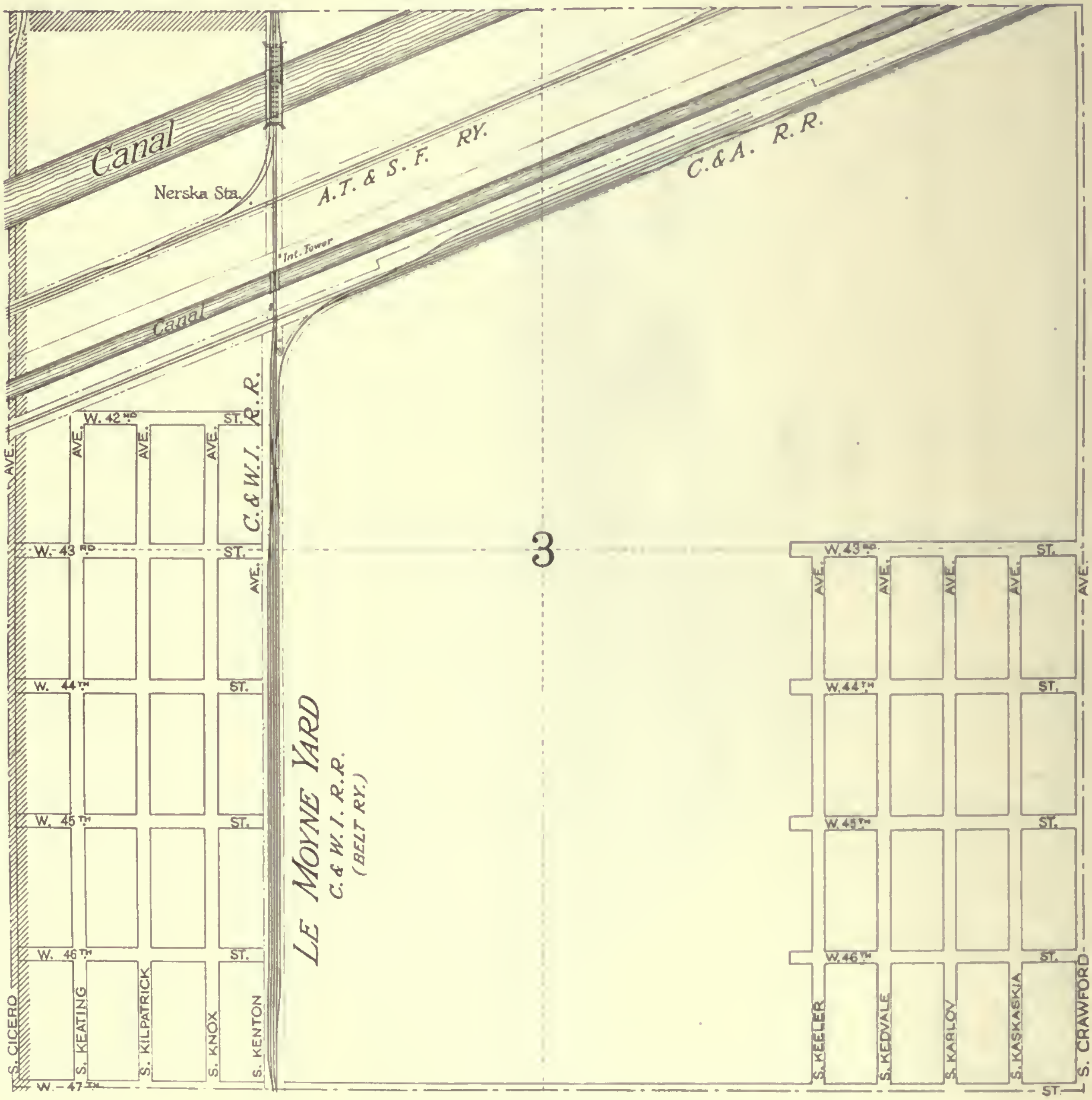

FIG. 165. SECTION MAP, INDEX NO. 71

Section 3 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

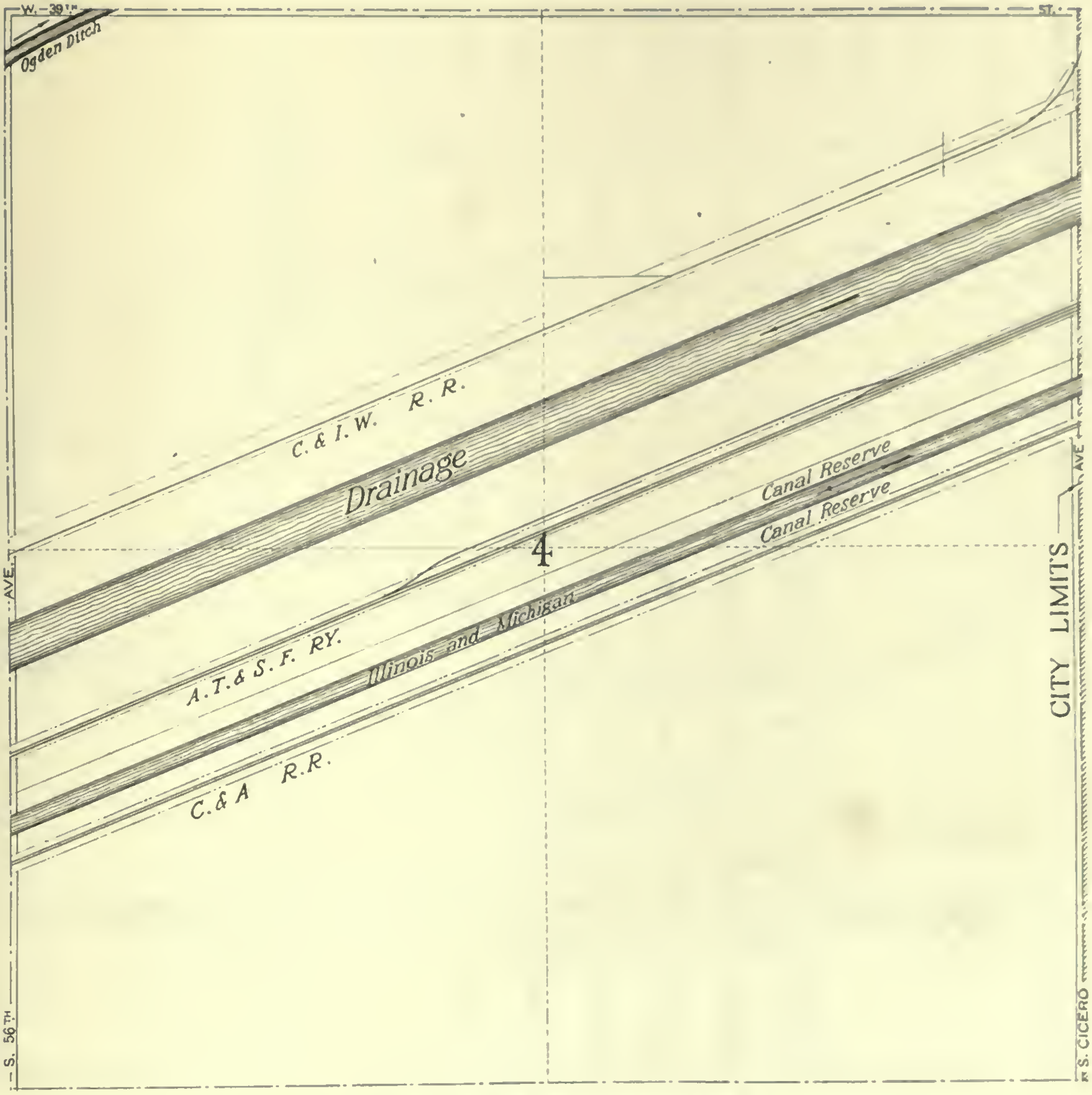

FIG. 166. SECTION MAP, INDEX NO. 72
Section 4 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″=800′

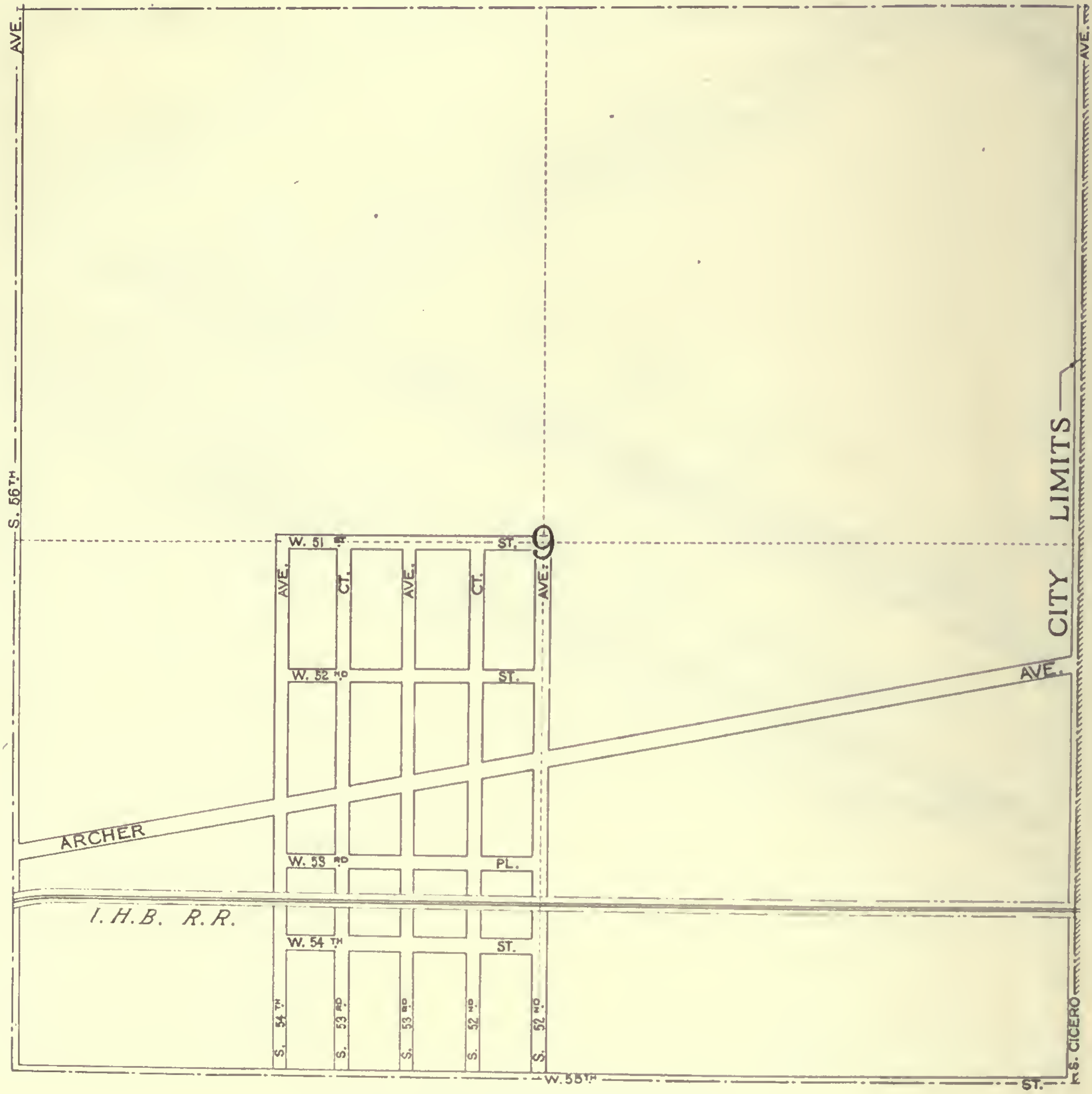

FIG. 167. SECTION MAP, INDEX NO. 73

Section 9 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

FIG. 168. SECTION MAP, INDEX NO. 74

Section 10 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale : 1" = 800'

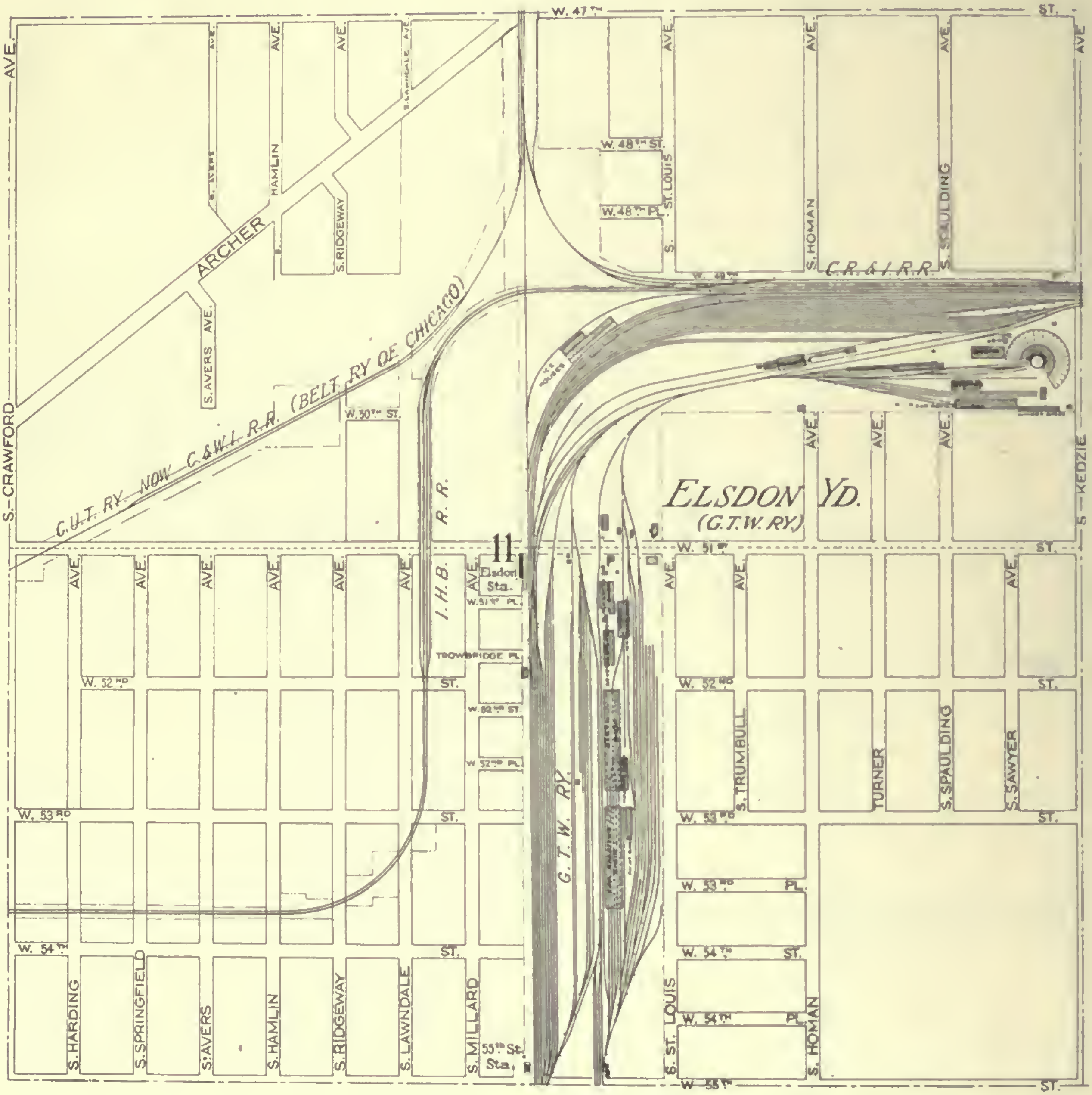

FIG. 169. SECTION MAP, INDEX NO. 75

Section 11 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

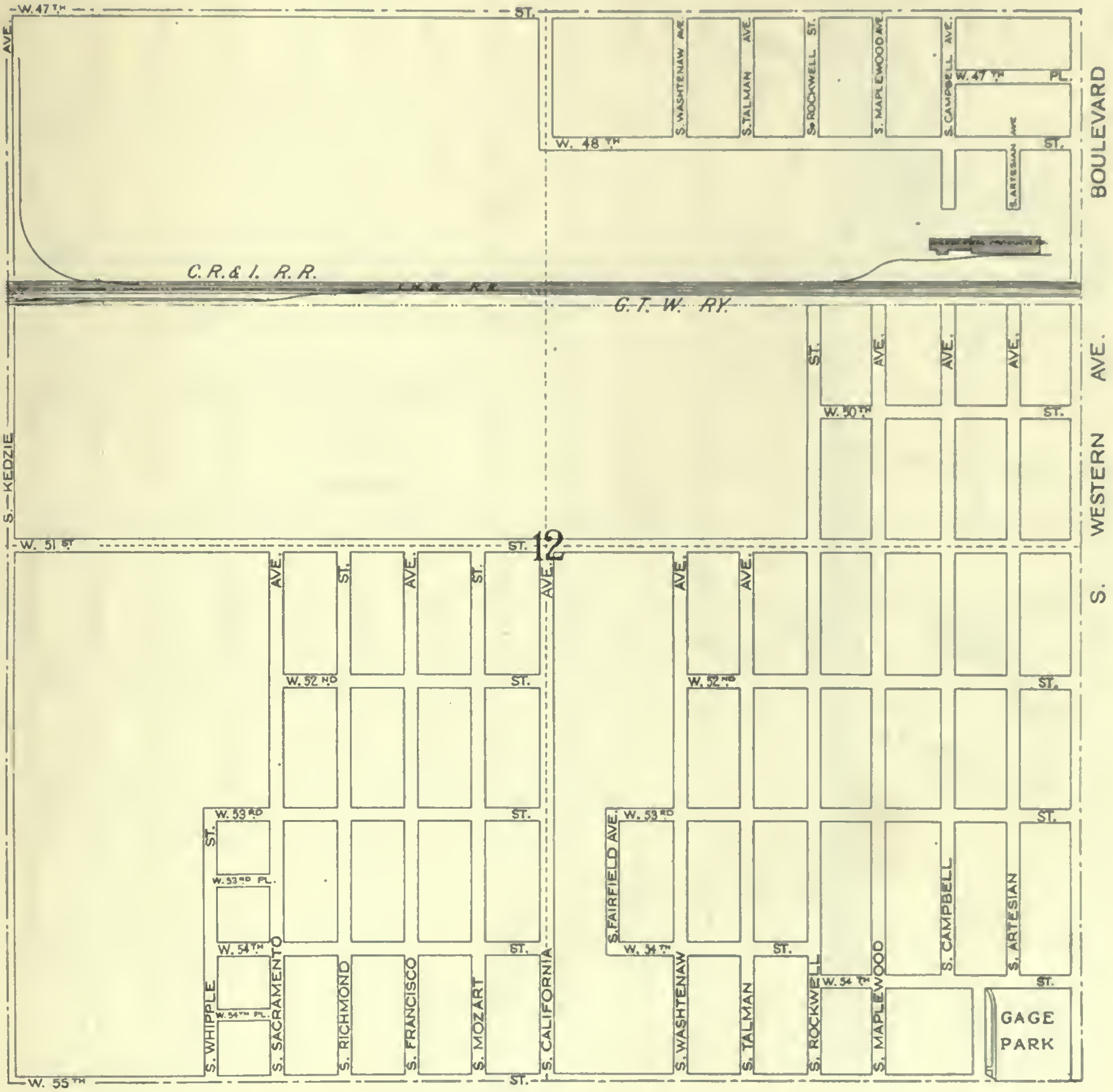

FIG. 170. SECTION MAP, INDEX NO. 76

Section 12 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

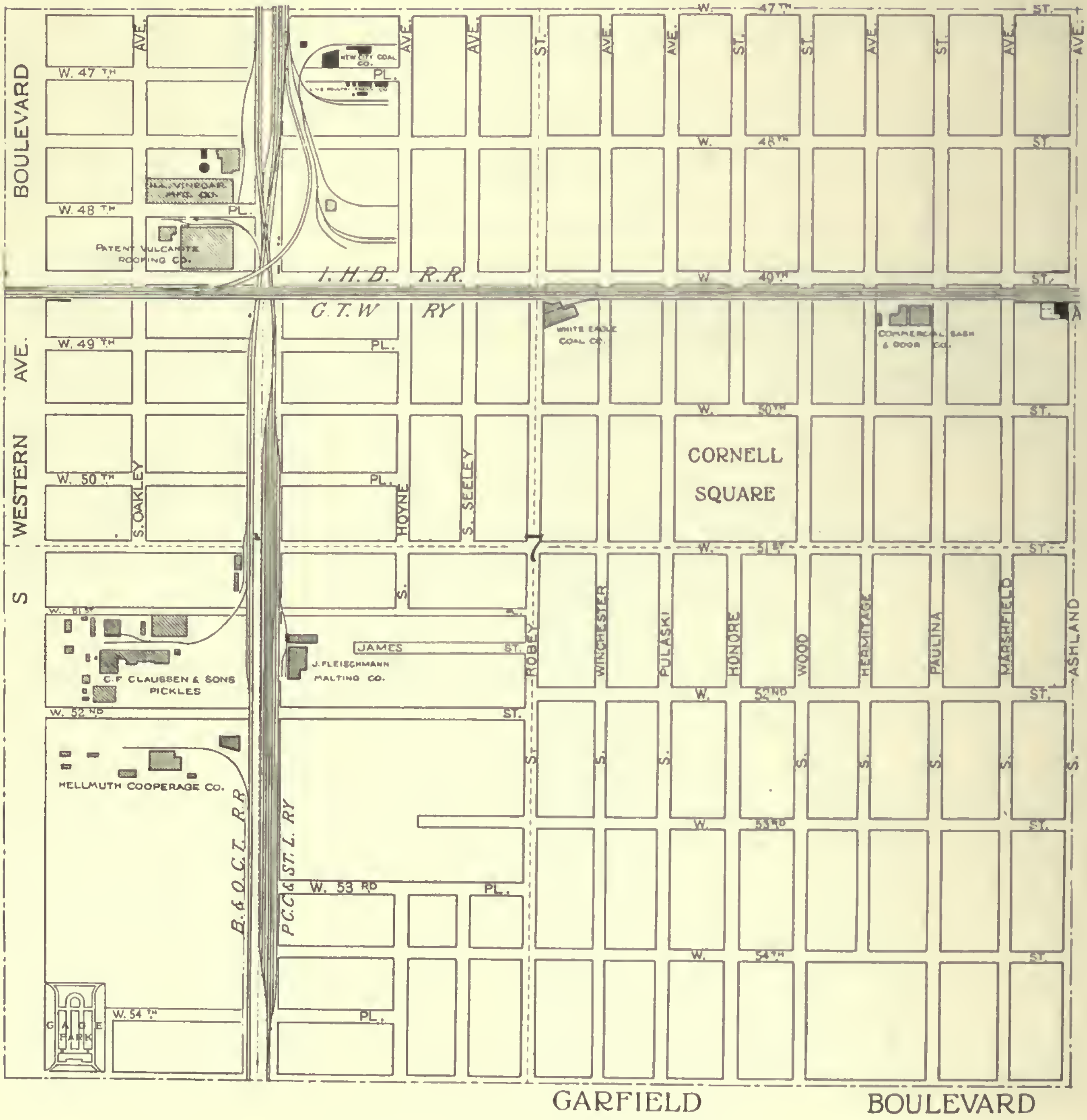

FIG. 171. SECTION MAP, INDEX NO. 77

Section 7 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

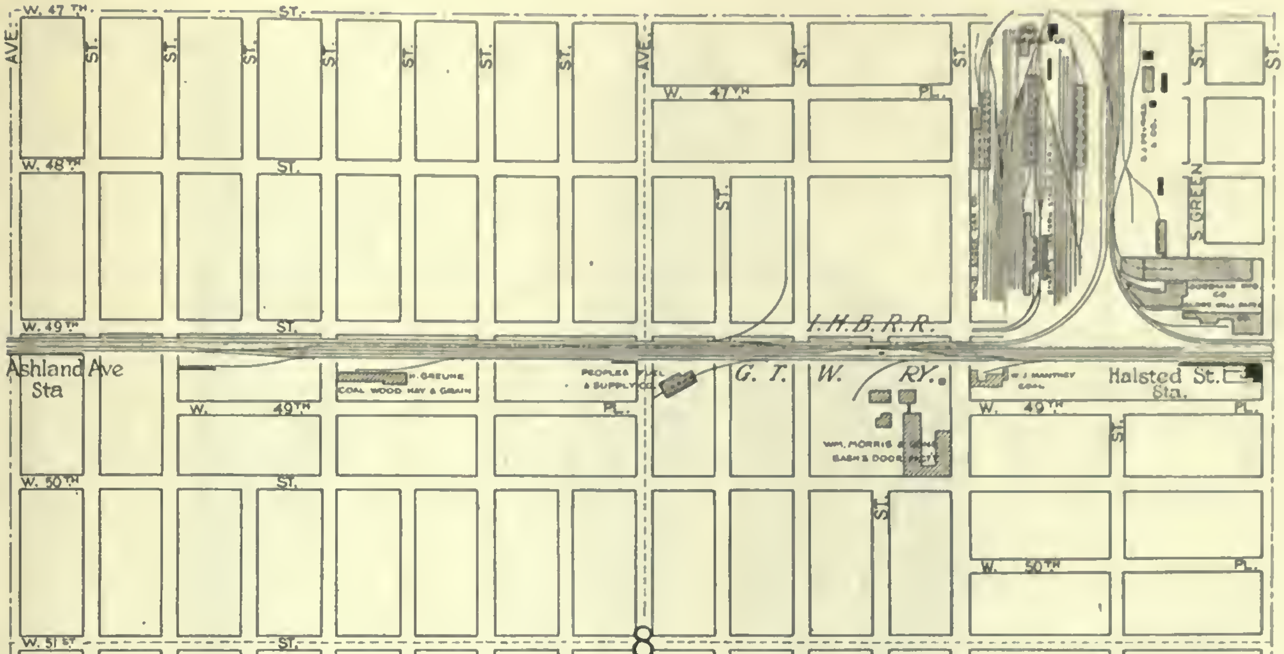

FIG. 172. SECTION MAP, INDEX NO. 78

Section 8 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

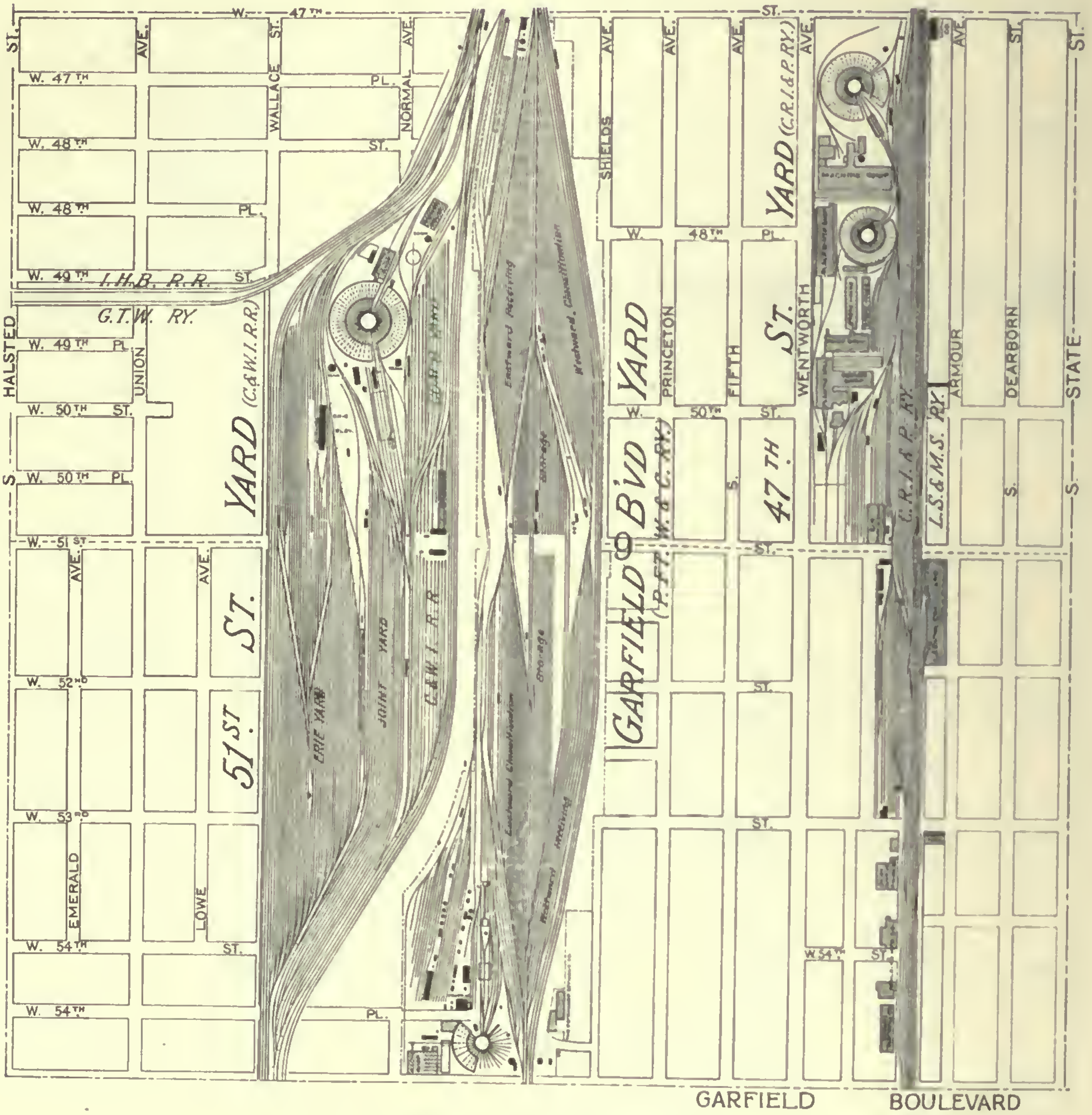

FIG. 173. SECTION MAP, INDEX NO. 79

Section 9 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″=800′

FIG. 174. SECTION MAP, INDEX NO. 80

Section 10 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

FIG. 175. SECTION MAP, INDEX NO. 81

Fractional Sections 11 and 12 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

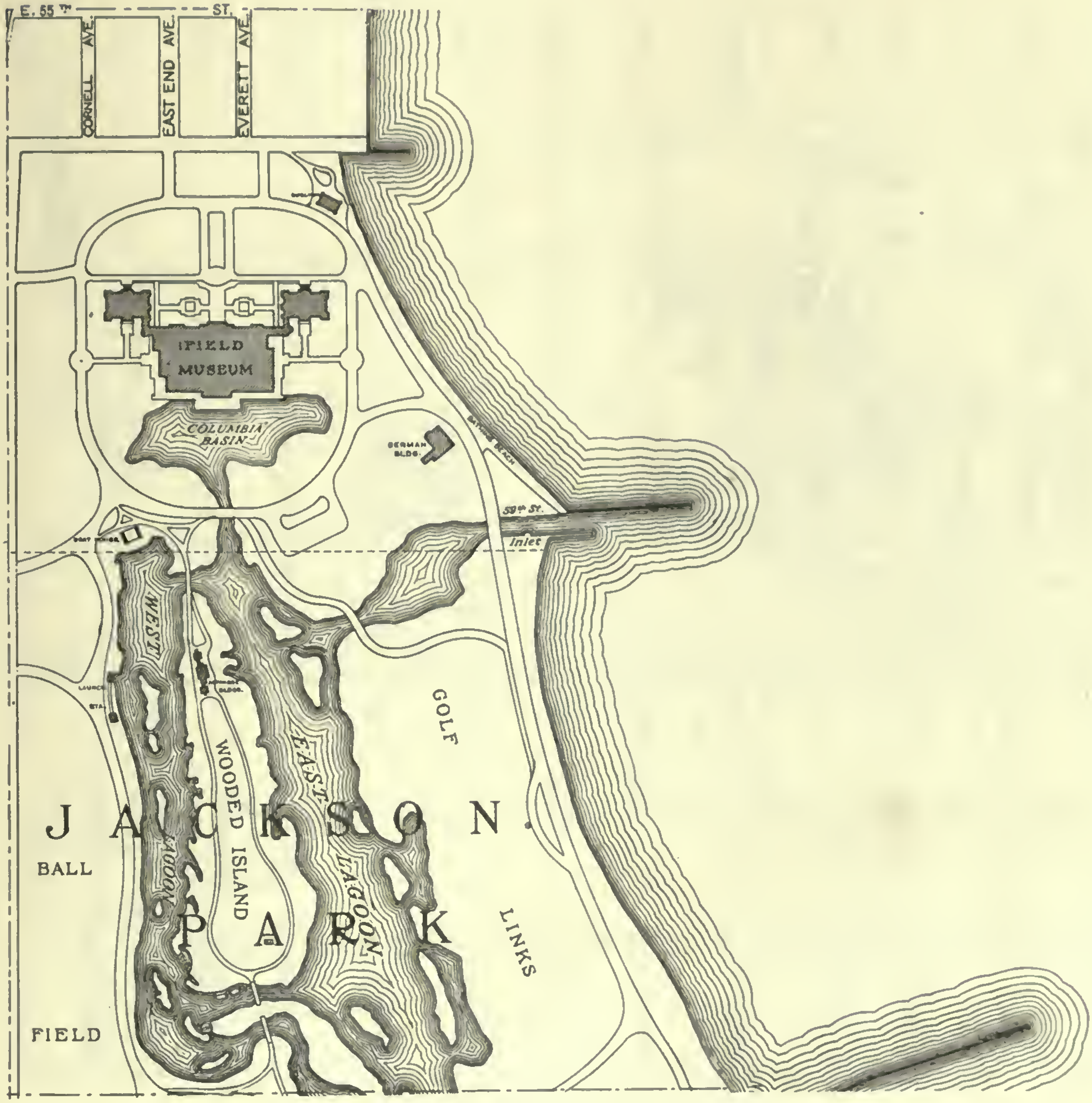

FIG. 176. SECTION MAP, INDEX NO. 82
Fractional Section 13 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1" = 800'

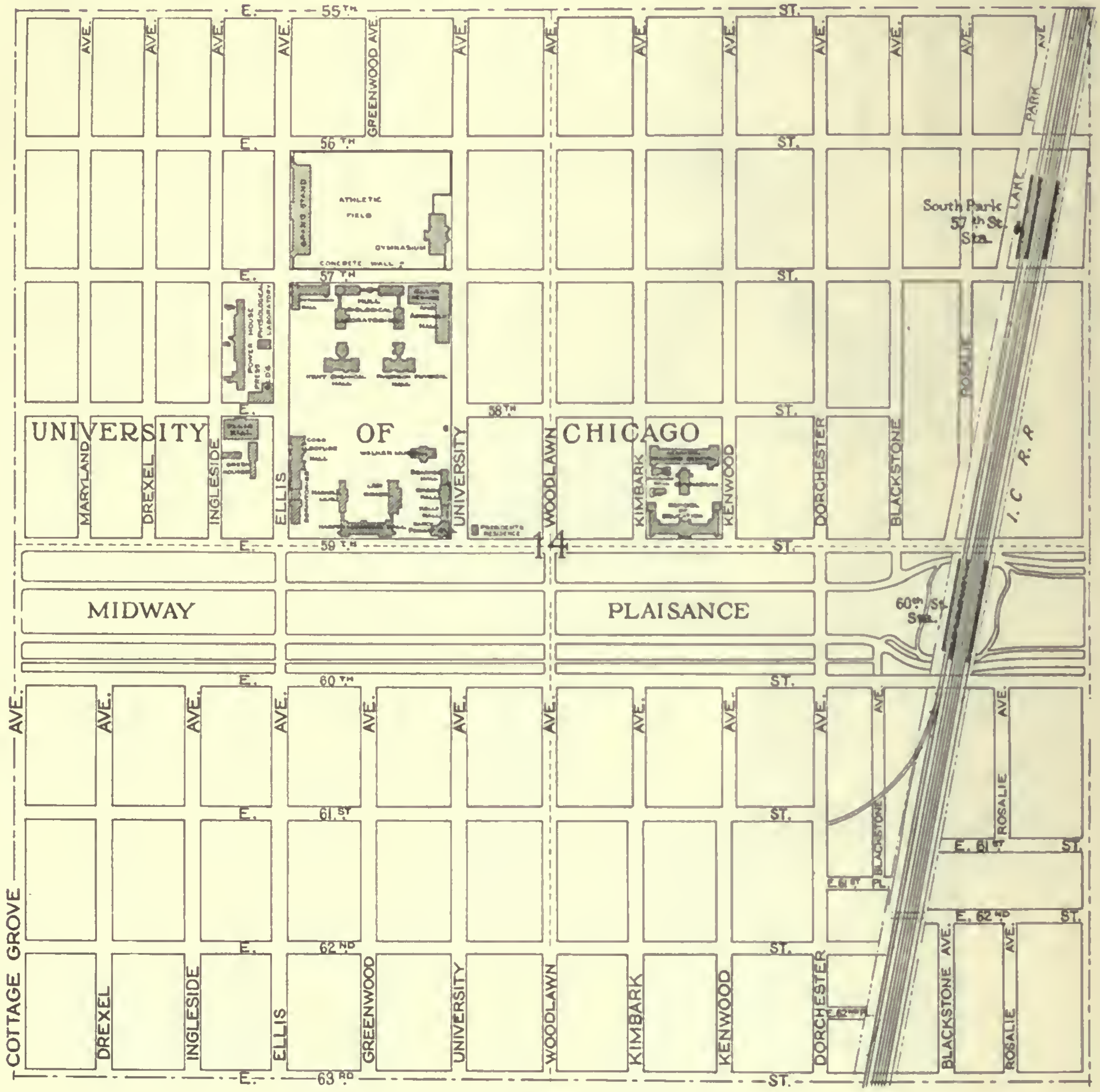

FIG. 177. SECTION MAP, INDEX NO. 83

Section 14 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

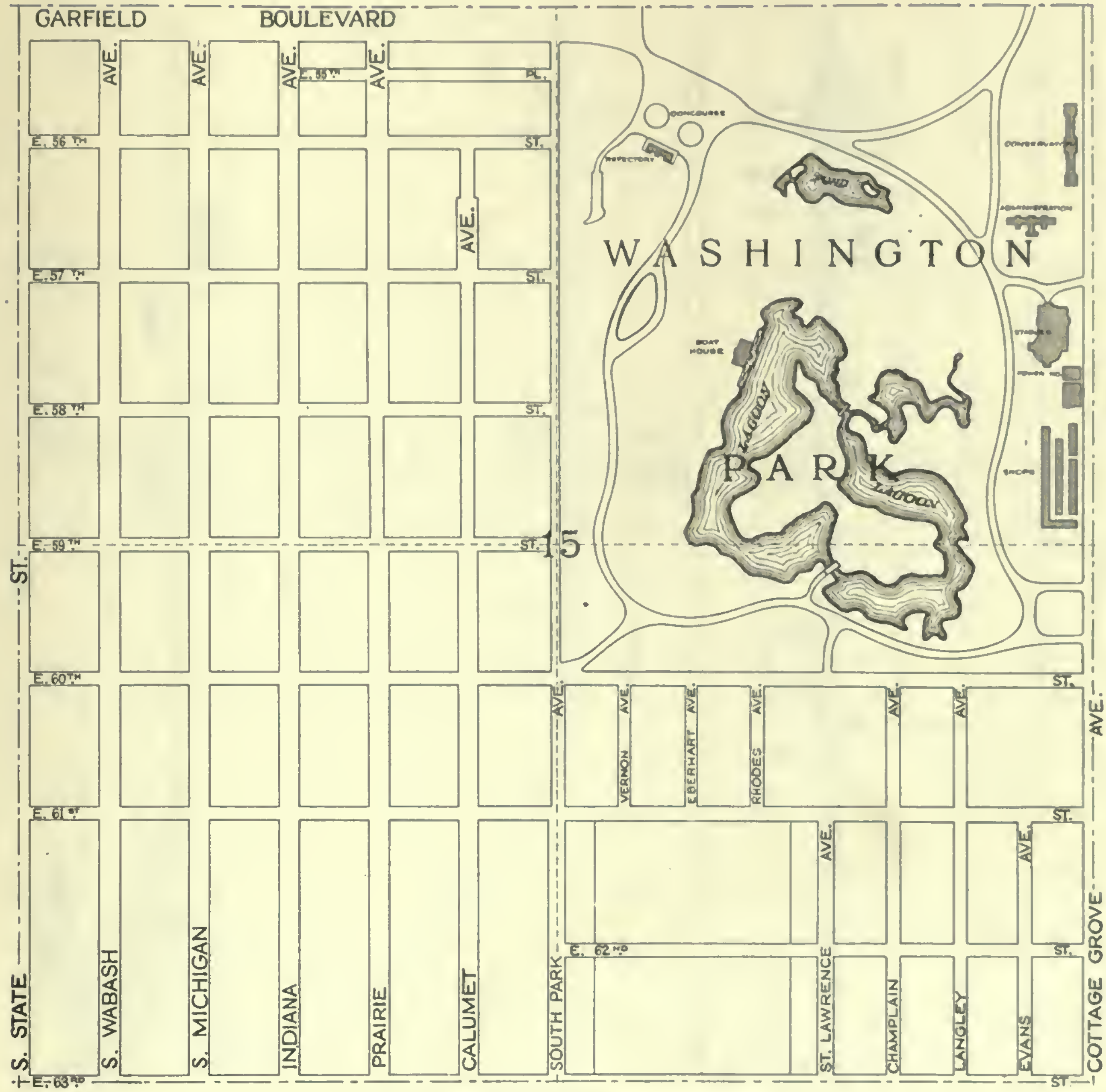

FIG. 178. SECTION MAP, INDEX NO. 84

Section 15— Twp. 38 N.— R. 14 E.— 3 P. M. Scale: 1″ = 800′

FIG. 179. SECTION MAP, INDEX NO. 85

Section 16 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

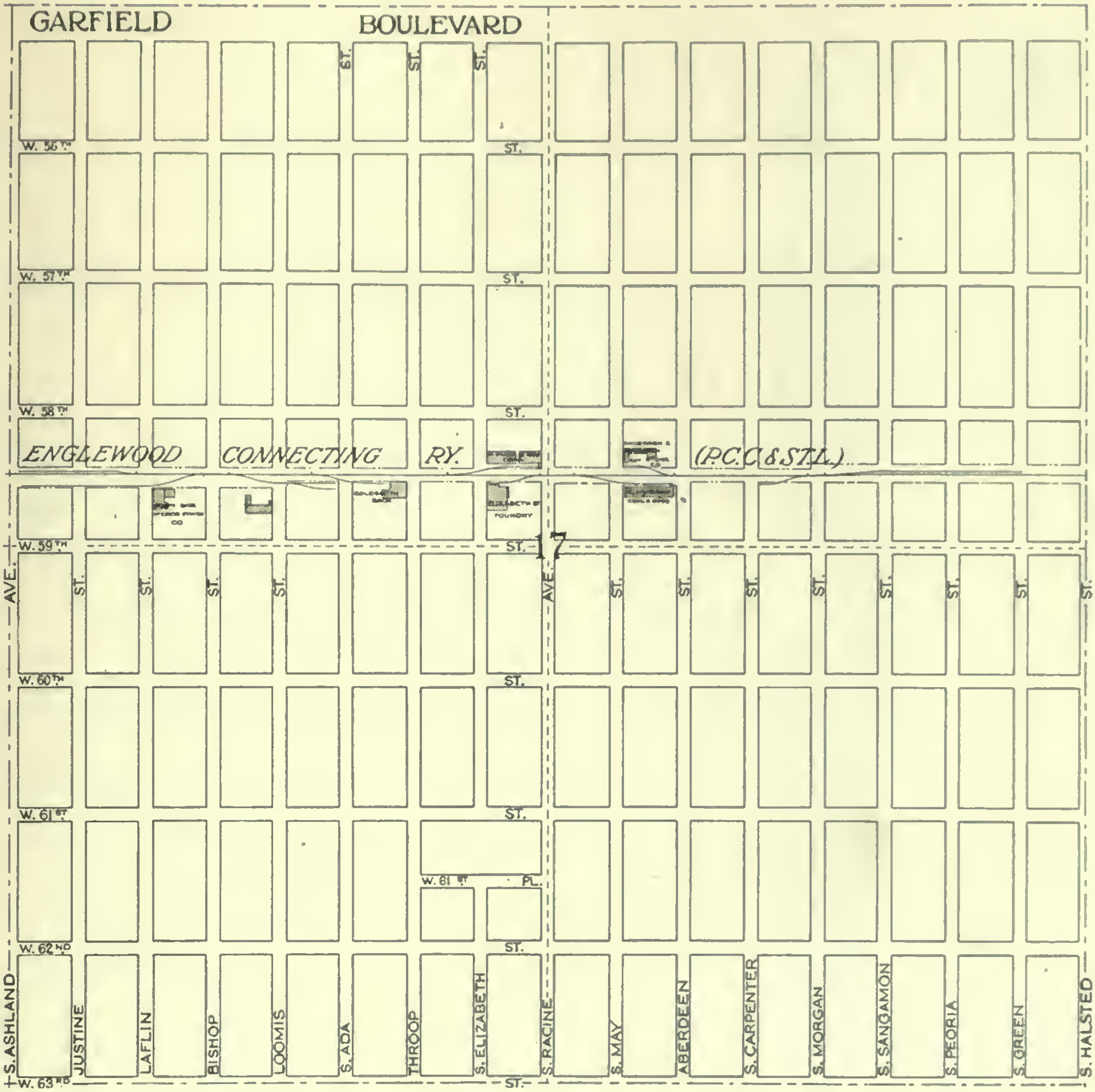

FIG. 180. SECTION MAP, INDEX NO. 86

Section 17 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

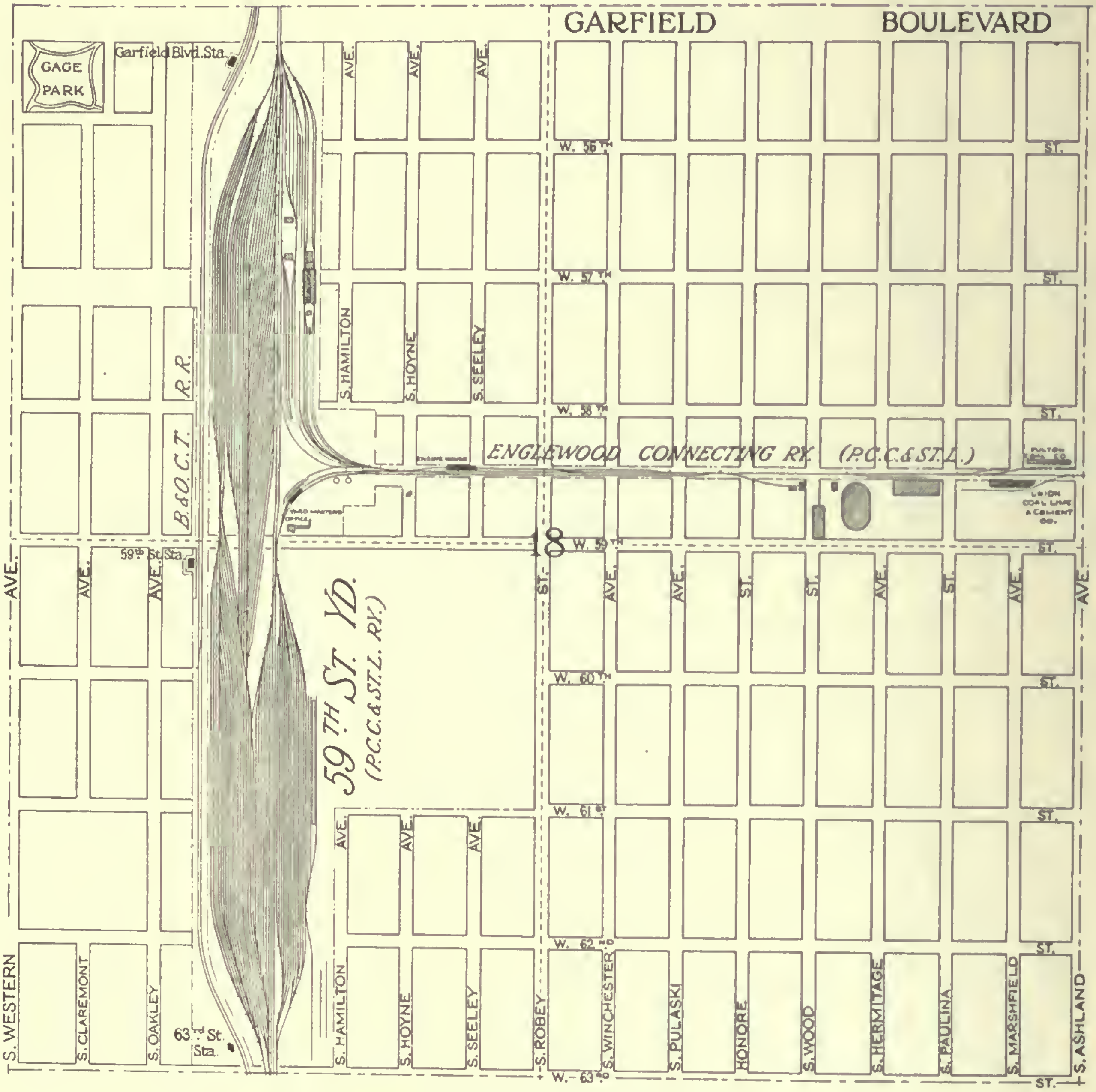

FIG. 181. SECTION MAP, INDEX NO. 87
Section 18 — Twp. 38 N.— R. 14 E. — 3 P. M. Scale: 1″ = 800′

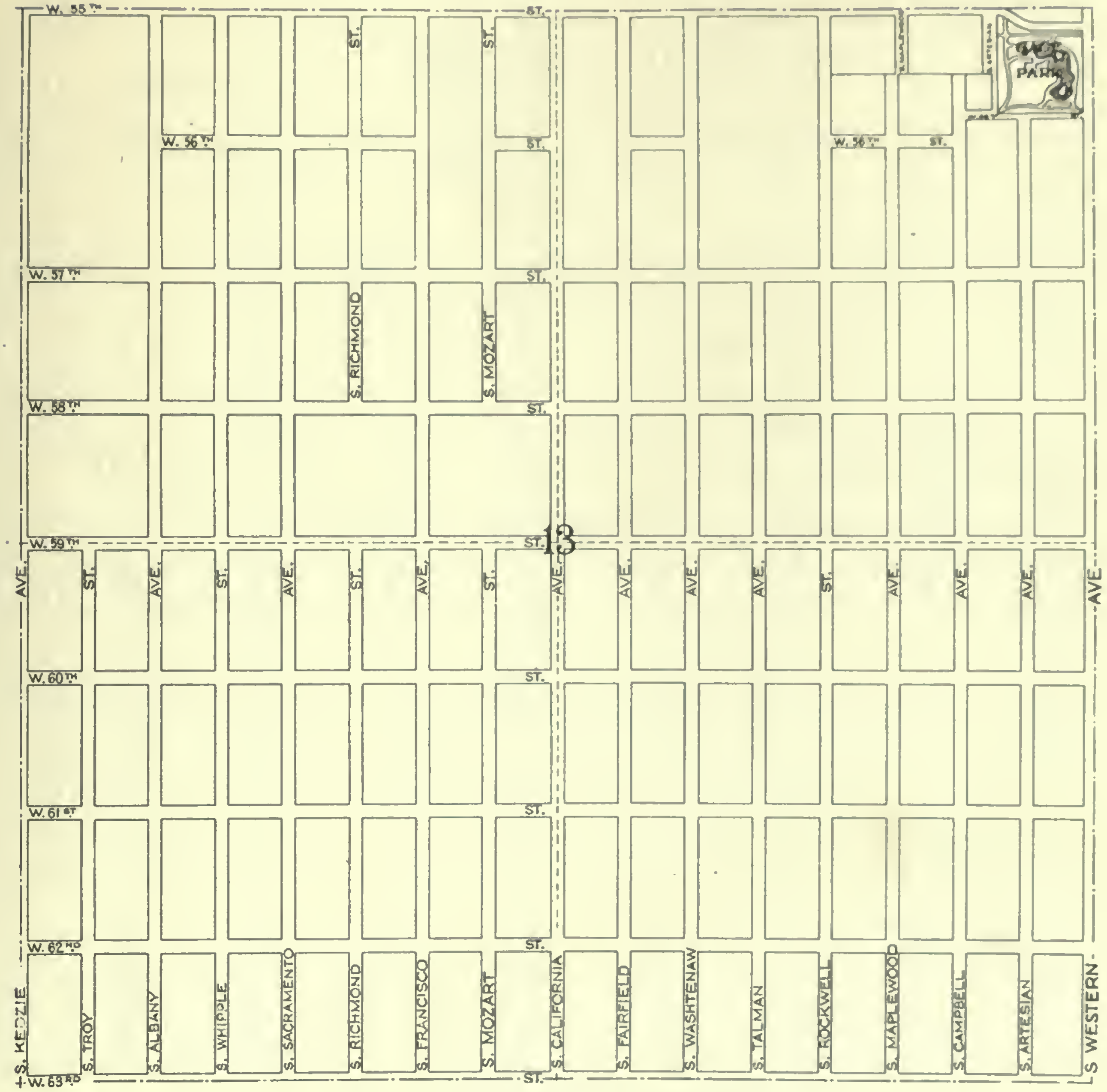

FIG. 182. SECTION MAP, INDEX NO. 88

Section 13 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″=800′

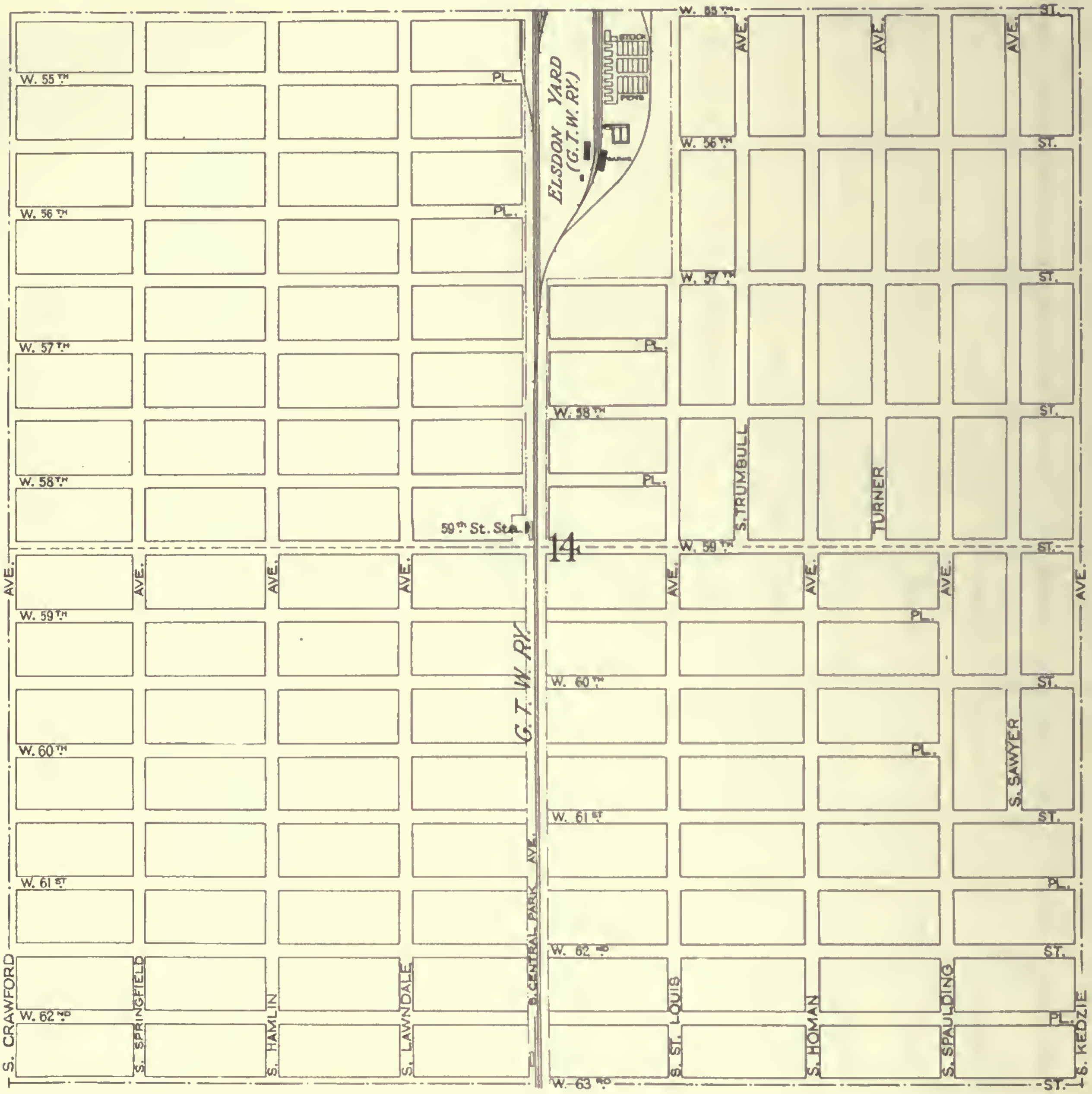

FIG. 183. SECTION MAP, INDEX NO. 89

Section 14 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

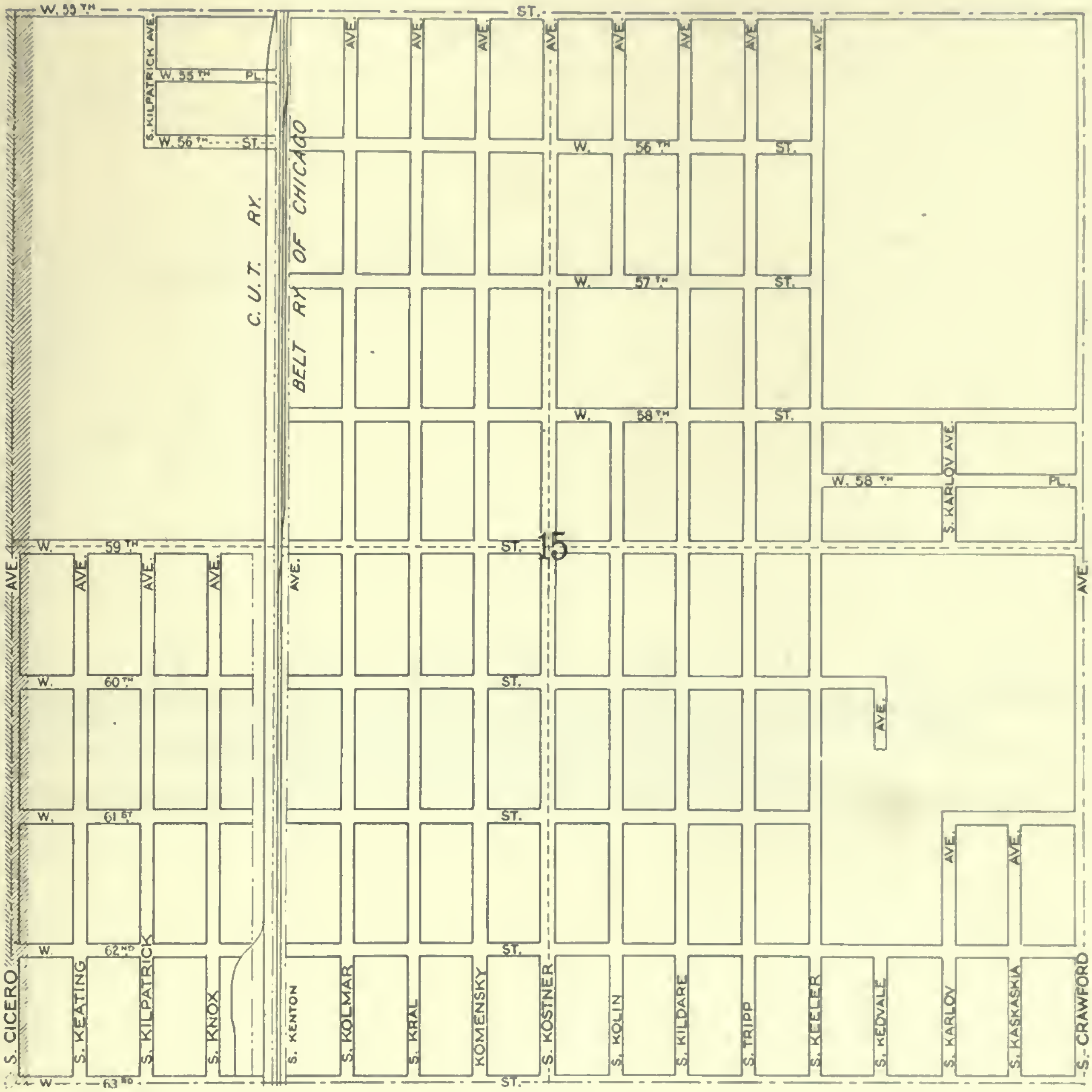

FIG. 184. SECTION MAP, INDEX NO. 90

Section 15 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

FIG. 185. SECTION MAP. INDEX NO. 91
Section 16 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

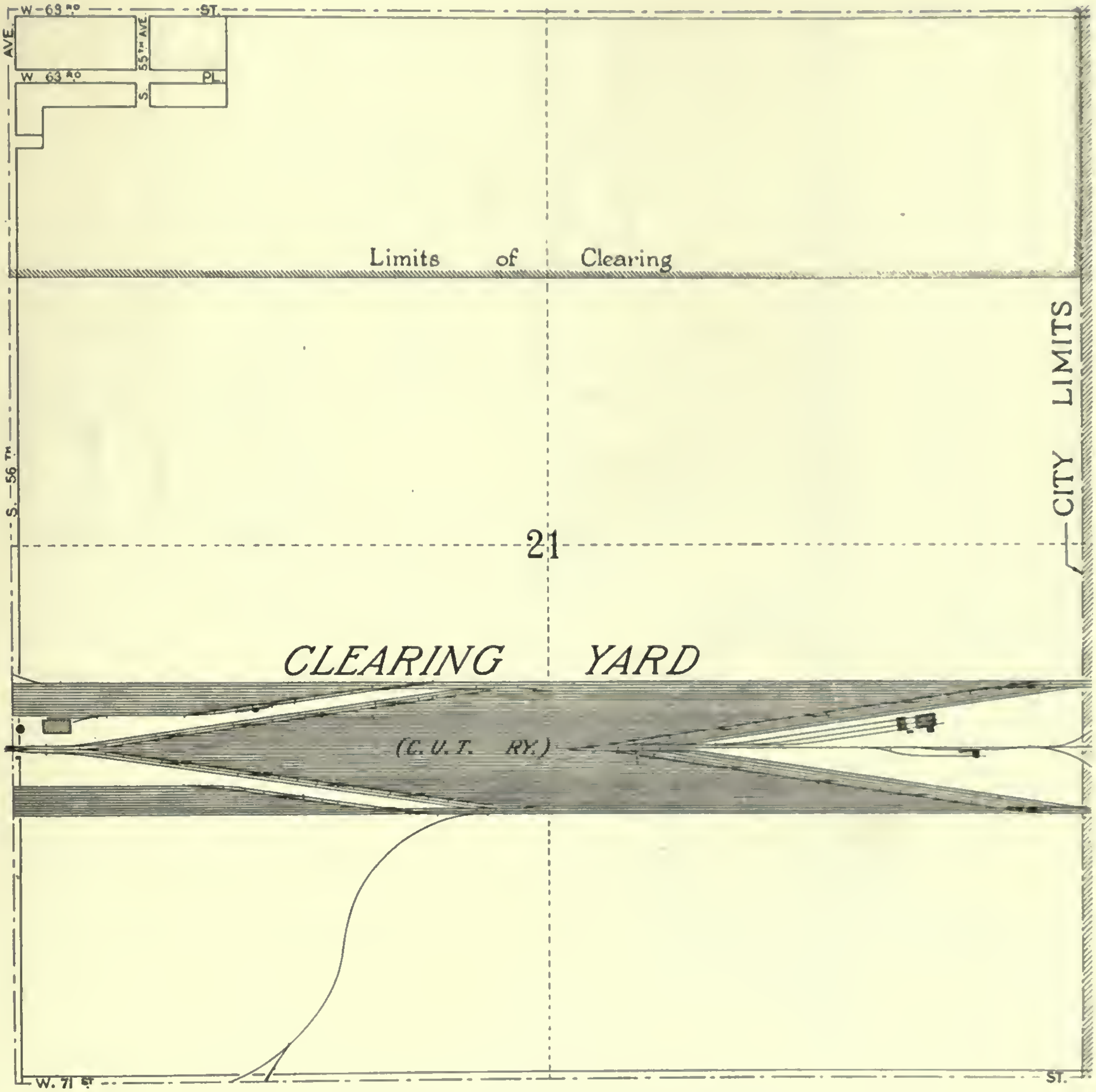

FIG. 186. SECTION MAP, INDEX NO. 92
Section 21 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

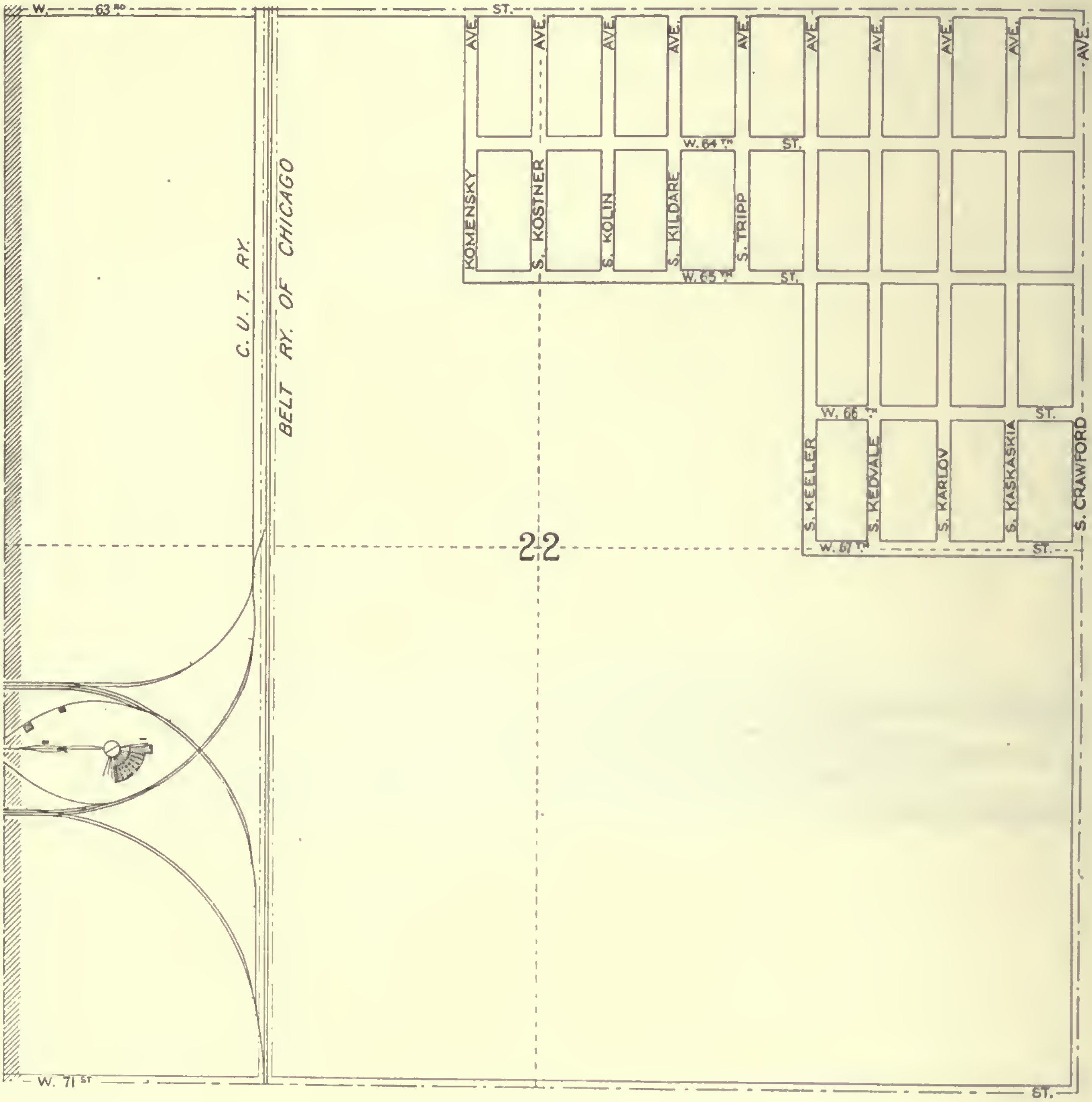

FIG. 187. SECTION MAP, INDEX NO. 93
Section 22 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

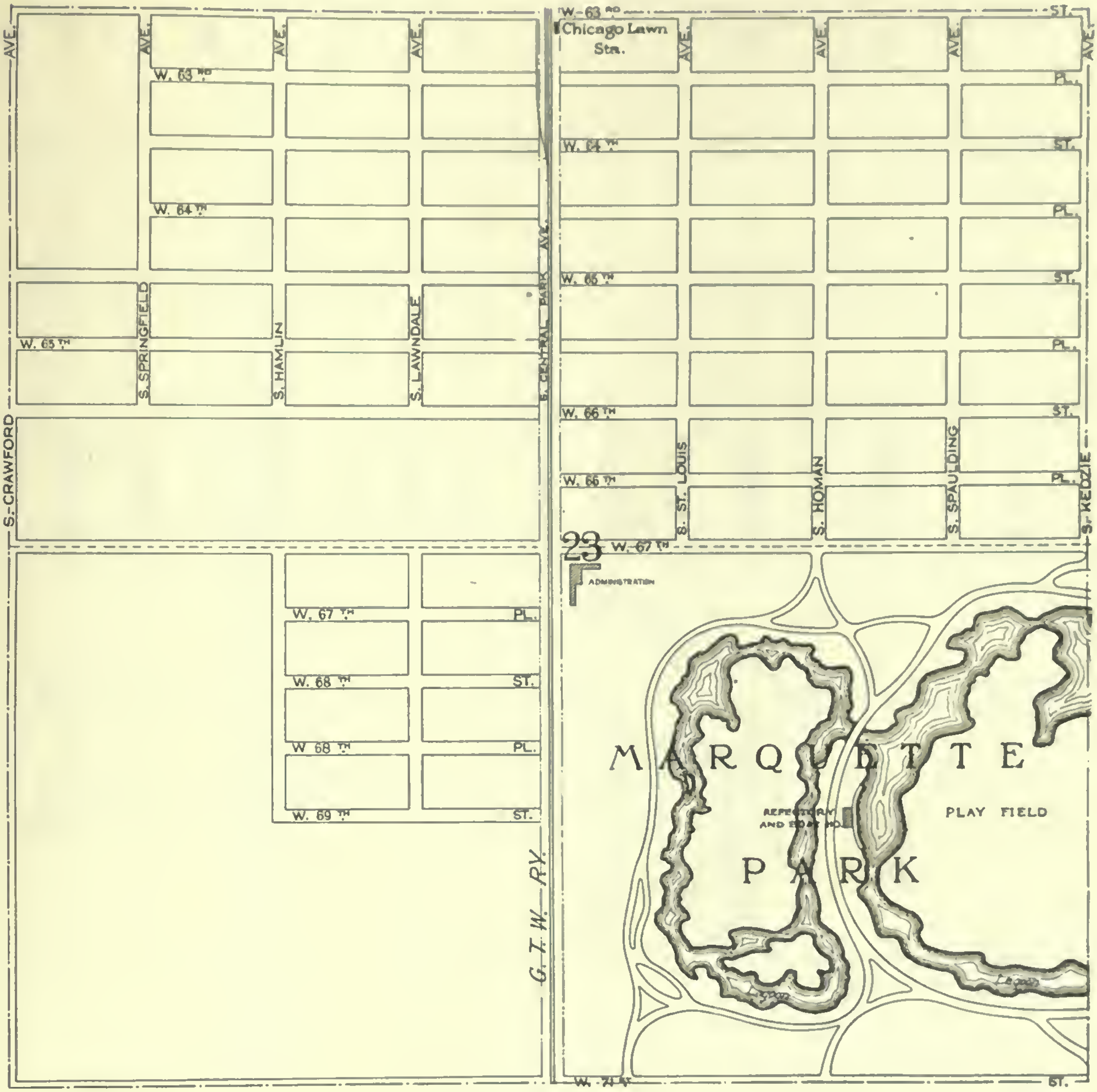

FIG. 188. SECTION MAP, INDEX NO. 94

Section 23 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

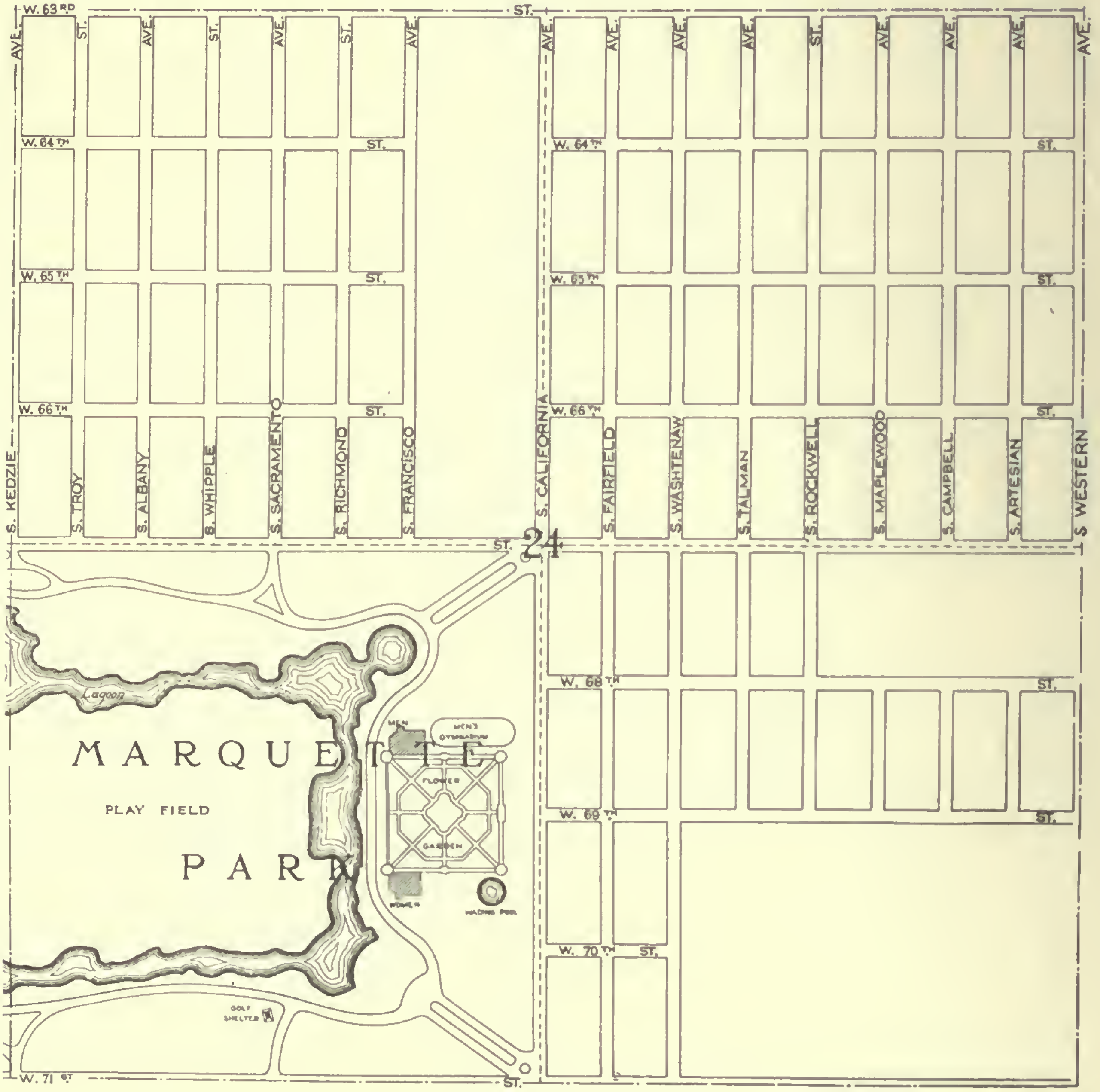

FIG. 189. SECTION MAP, INDEX NO. 95

Section 24 Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

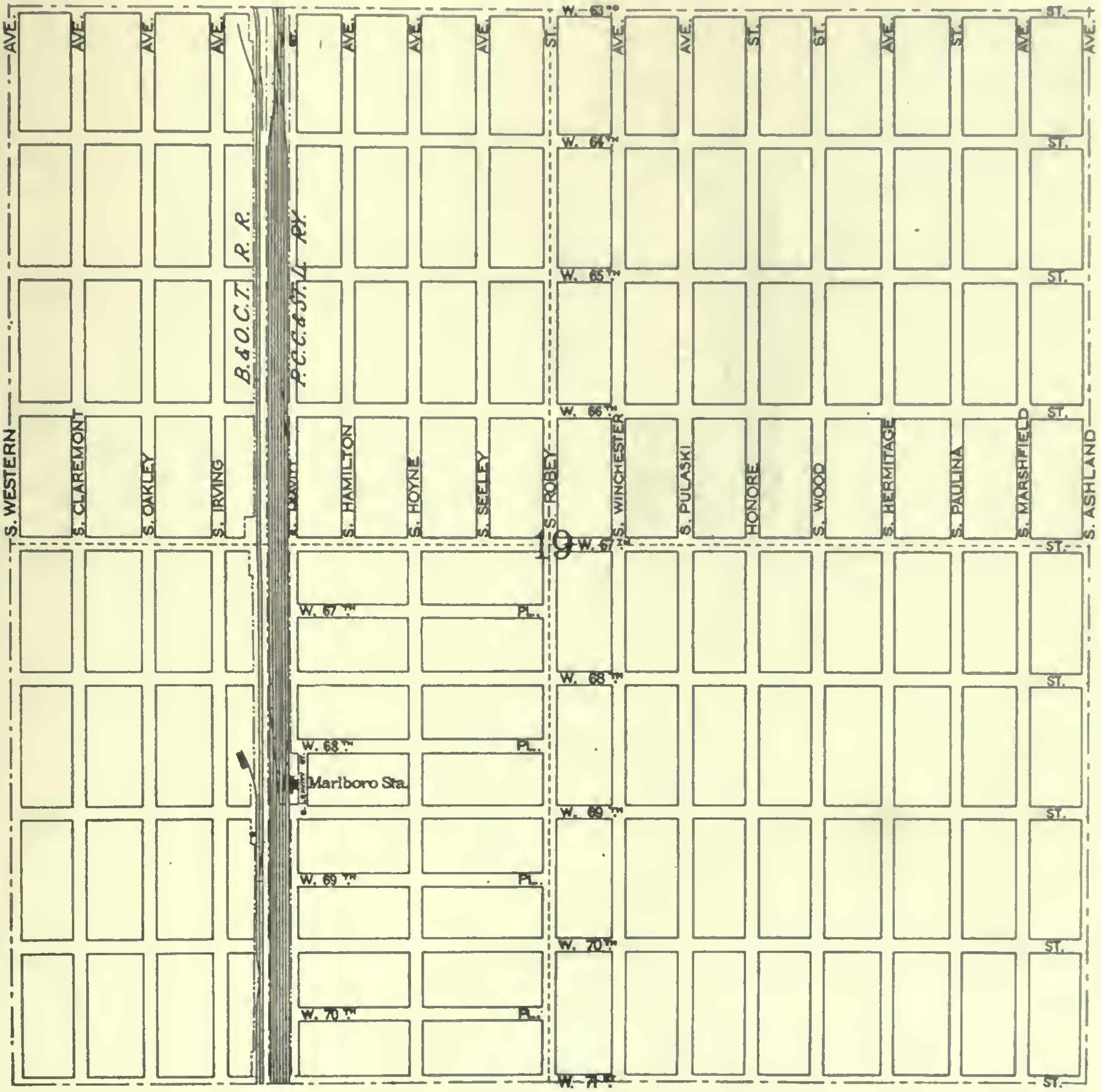

FIG. 190. SECTION MAP, INDEX NO. 96

Section 19 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

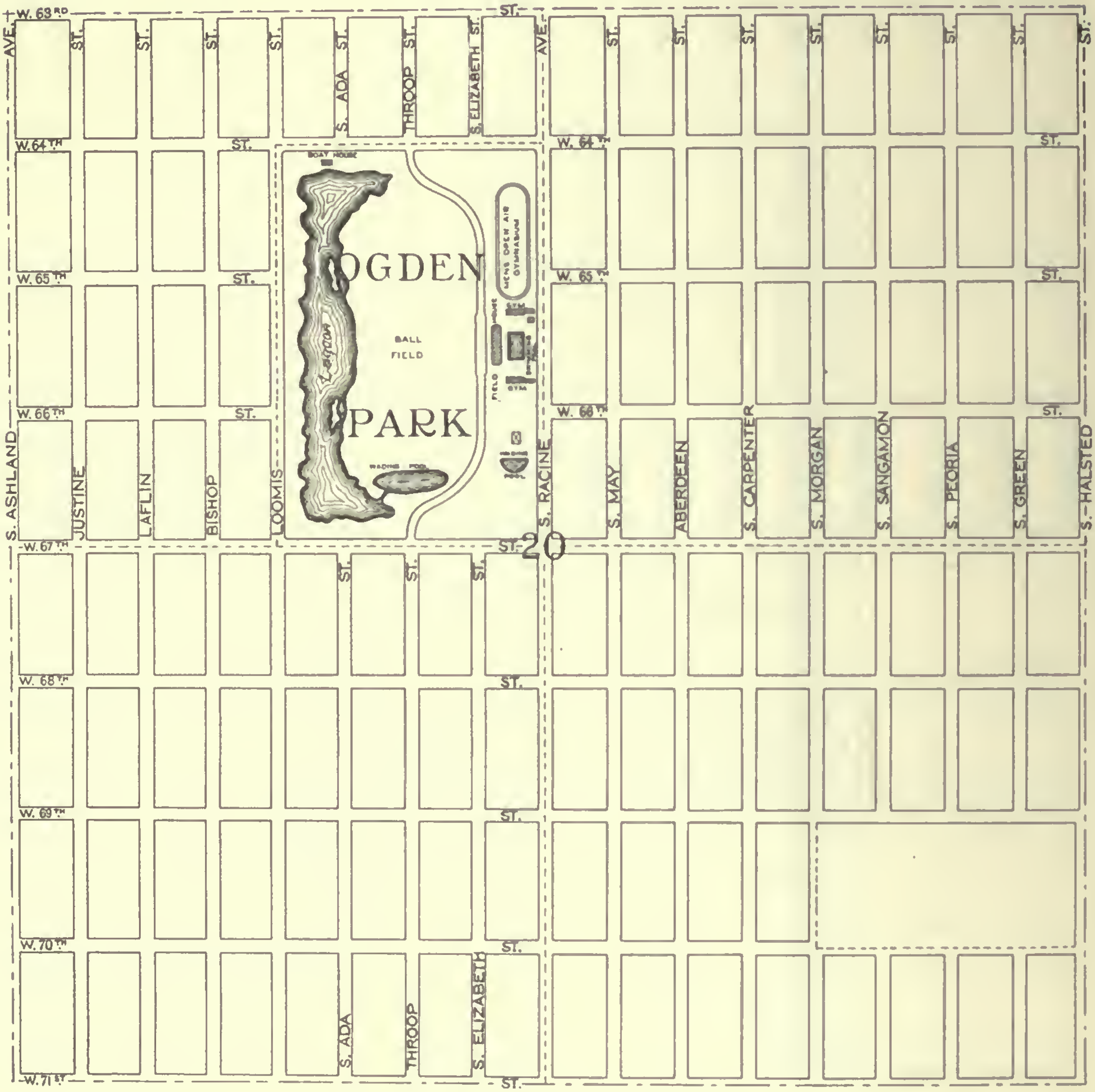

FIG. 191. SECTION MAP, INDEX NO. 97

Section 20 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

FIG. 192. SECTION MAP, INDEX NO. 98

Section 21 — Twp. 38 N.— R. 14 E.— 3 P. M. Scale: 1″ = 800′

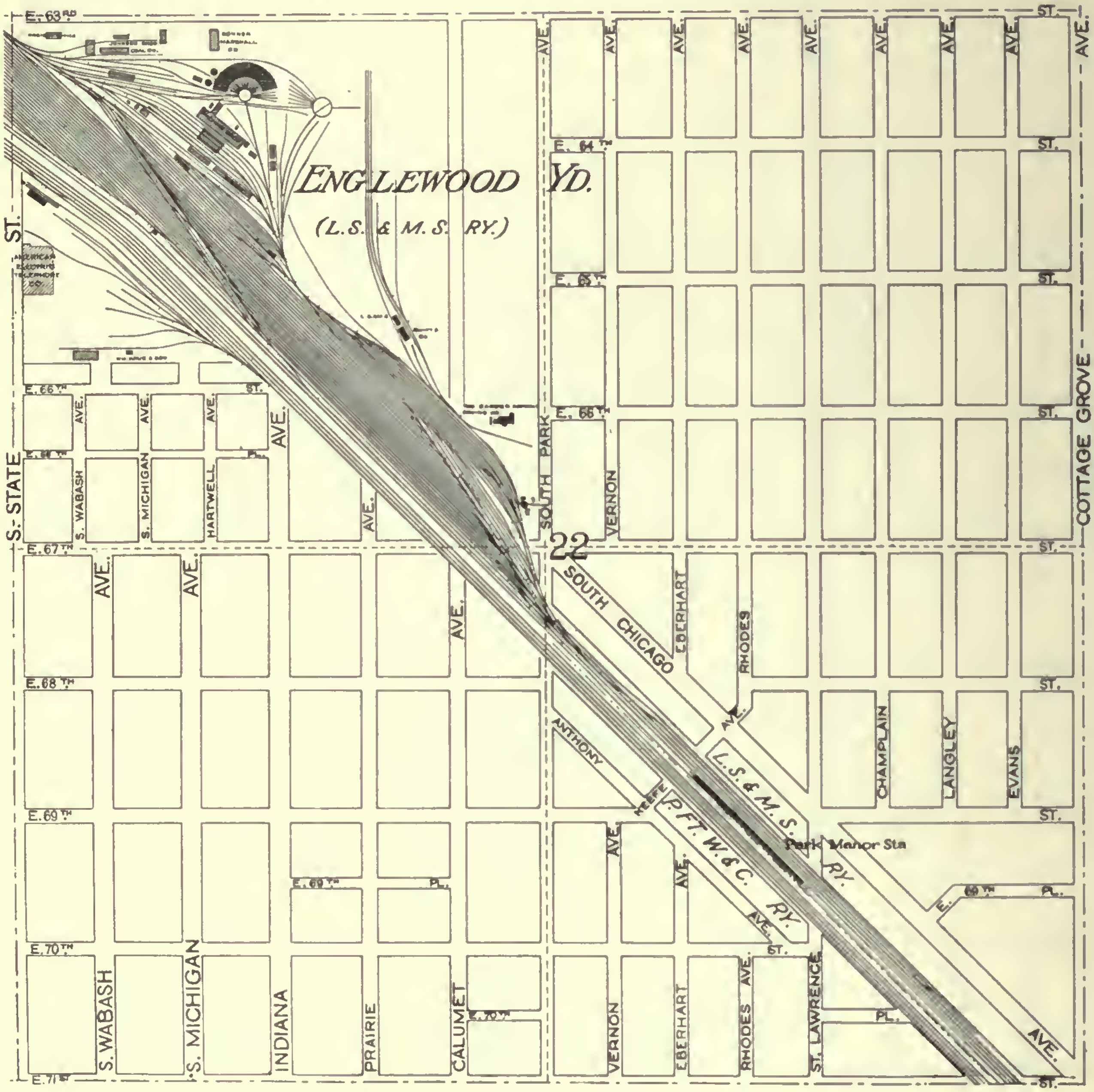

FIG. 193. SECTION MAP, INDEX NO. 99

Section 22 — Twp. 38 N.— R. 14 E.— 3 P. M. Scale: 1″ = 800′

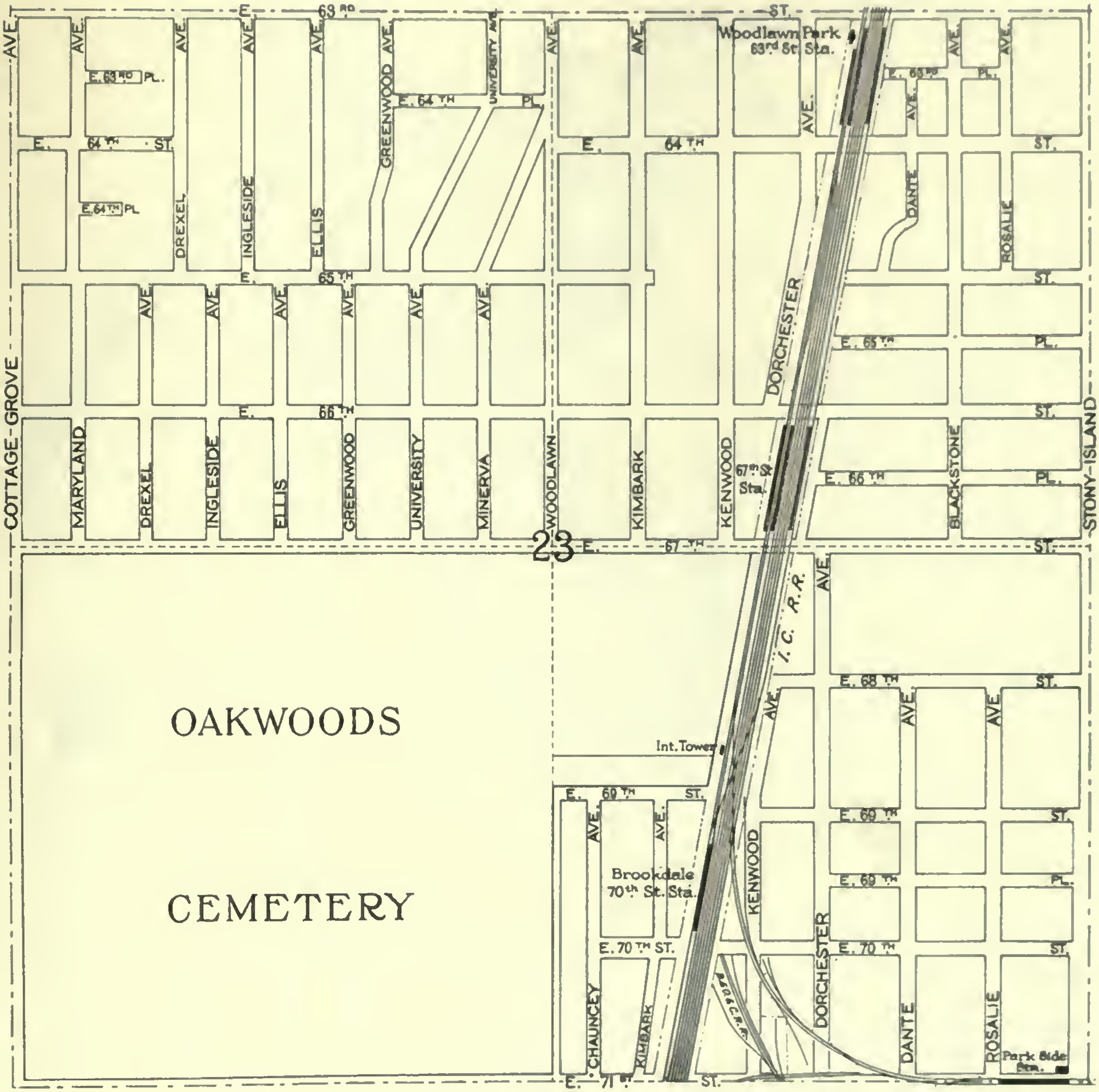

FIG. 194. SECTION MAP, INDEX NO. 100

Section 23 — Twp. 38 N.— R. 14 E.— 3 P. M. Scale: 1" = 800'

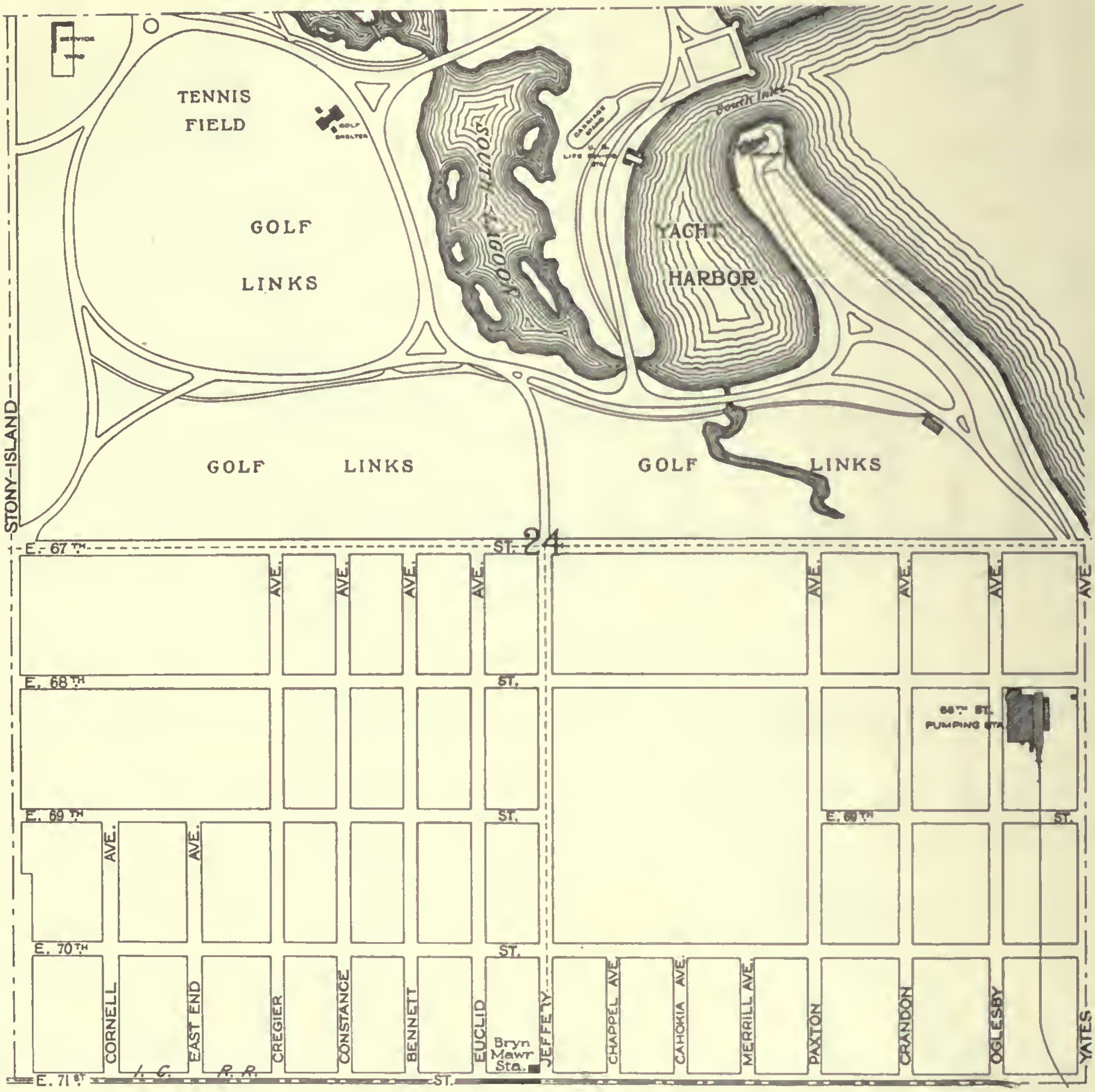

FIG. 195. SECTION MAP, INDEX NO. 101

Fractional Section 24 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″=800′

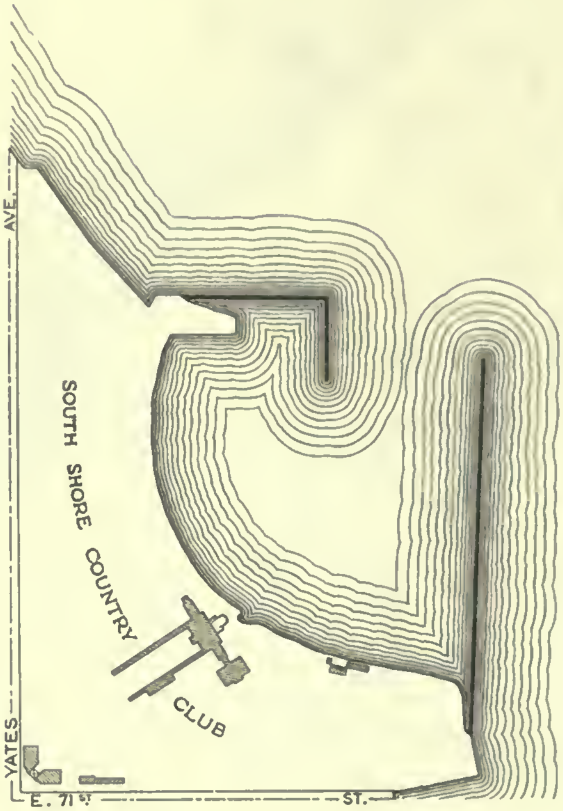

FIG. 196. SECTION MAP, INDEX NO. 102
Fractional Section 25 — Twp. 38 N. — R. 15 E. — 3 P. M. Scale: 1″ = 800′

FIG. 197. SECTION MAP, INDEX NO. 103

Fractional Section 30 — Twp. 38 N. — R. 15 E. — 3 P. M. Scale: 1″ = 800′

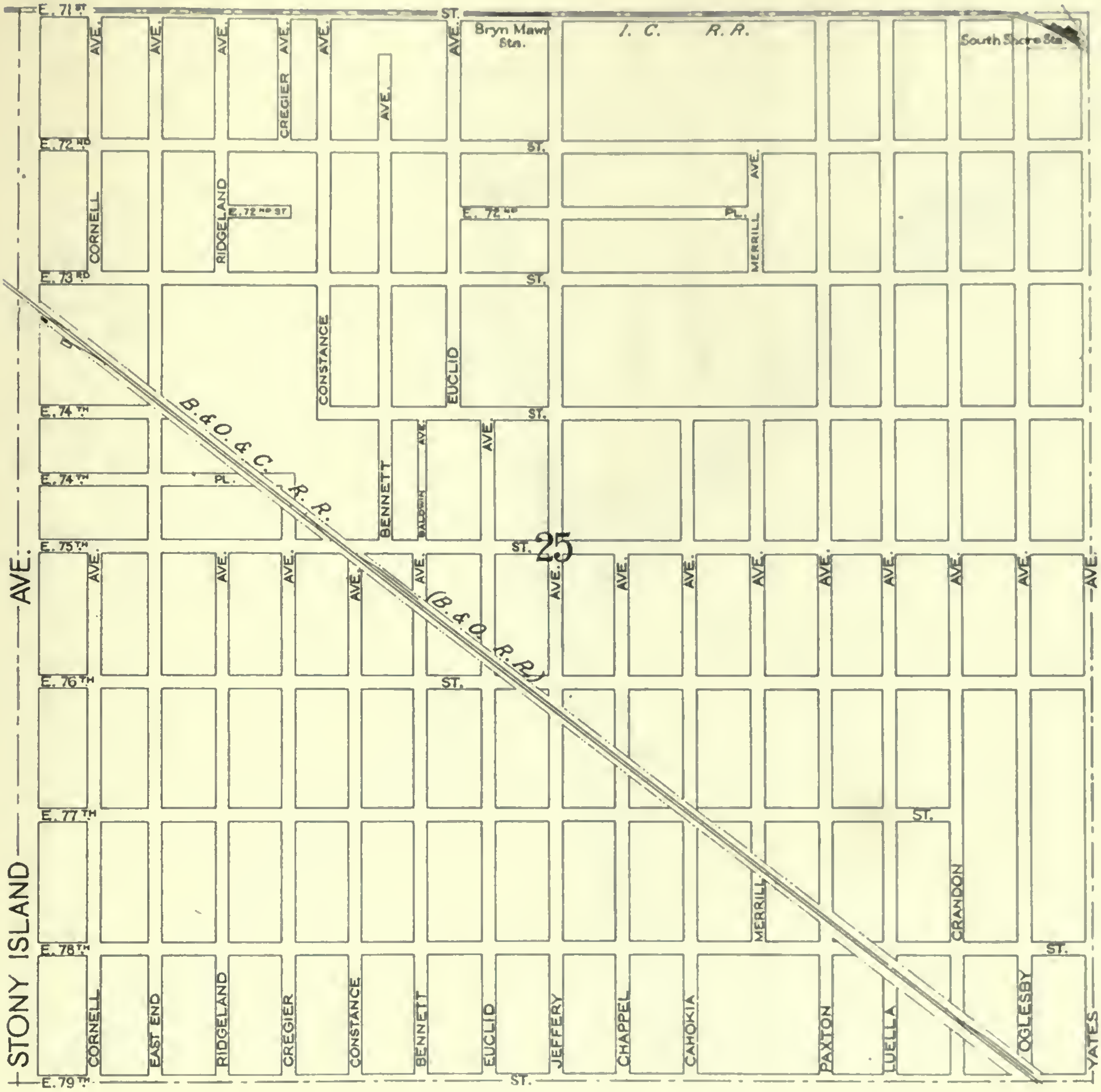

FIG. 198. SECTION MAP, INDEX NO. 104

Section 25 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

FIG. 199. SECTION MAP, INDEX NO. 105

Section 26 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

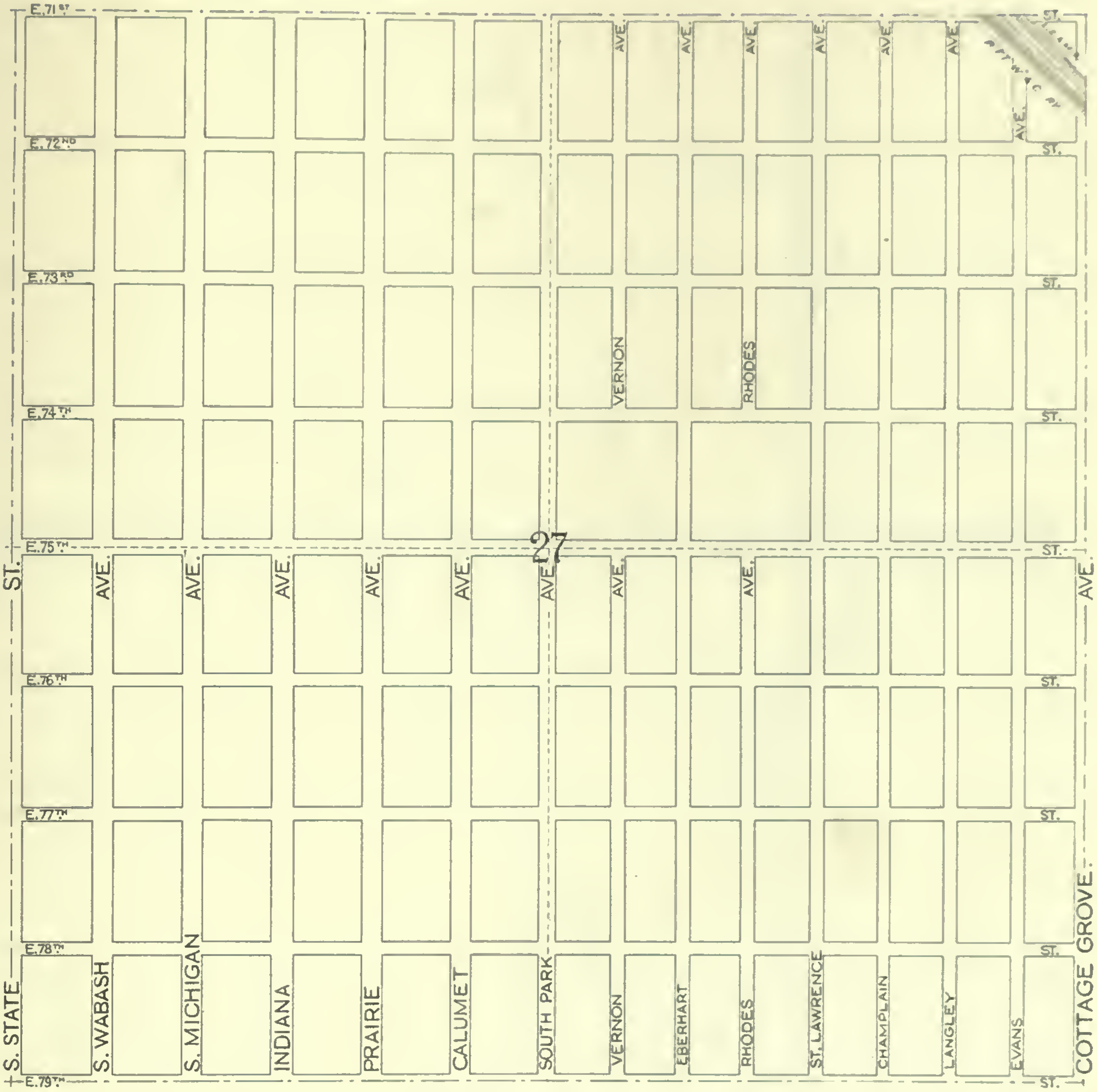

FIG. 200. SECTION MAP, INDEX NO. 106

Section 27 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

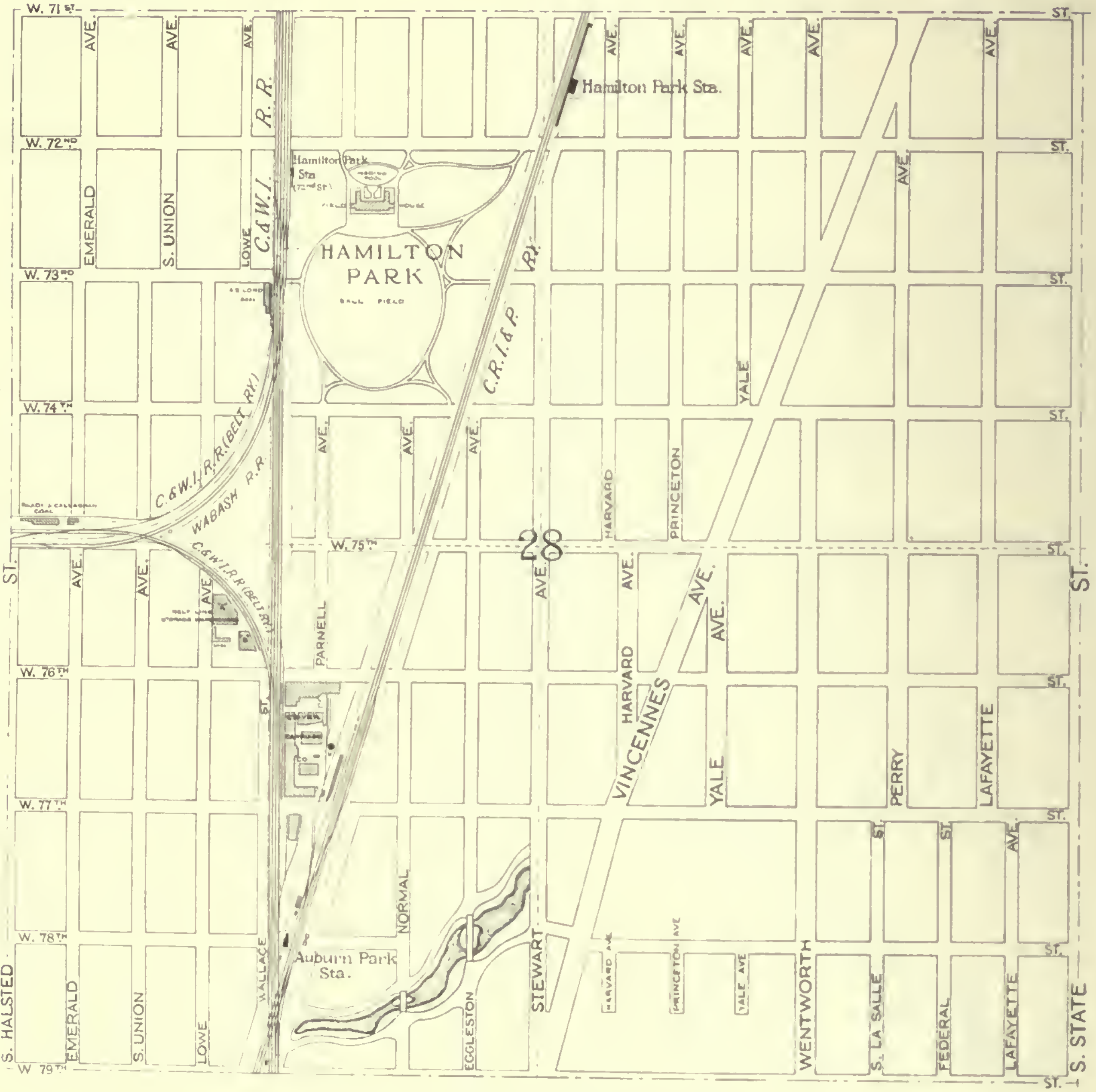

FIG. 201. SECTION MAP, INDEX NO. 107
Section 28 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

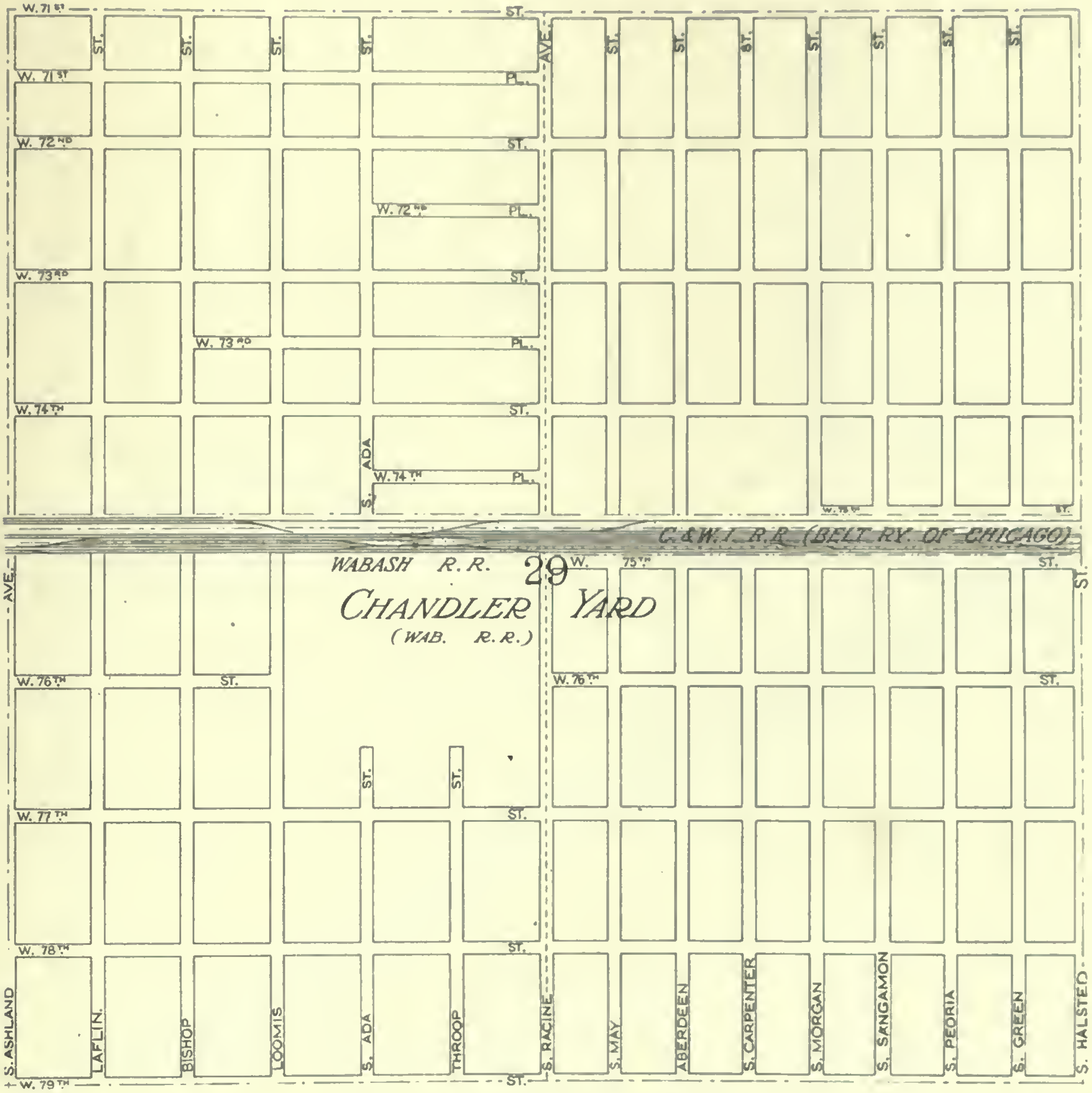

FIG. 202. SECTION MAP, INDEX NO. 108

Section 29—Twp. 38 N.—R. 14 E.—3 P. M. Scale: 1″ = 800′

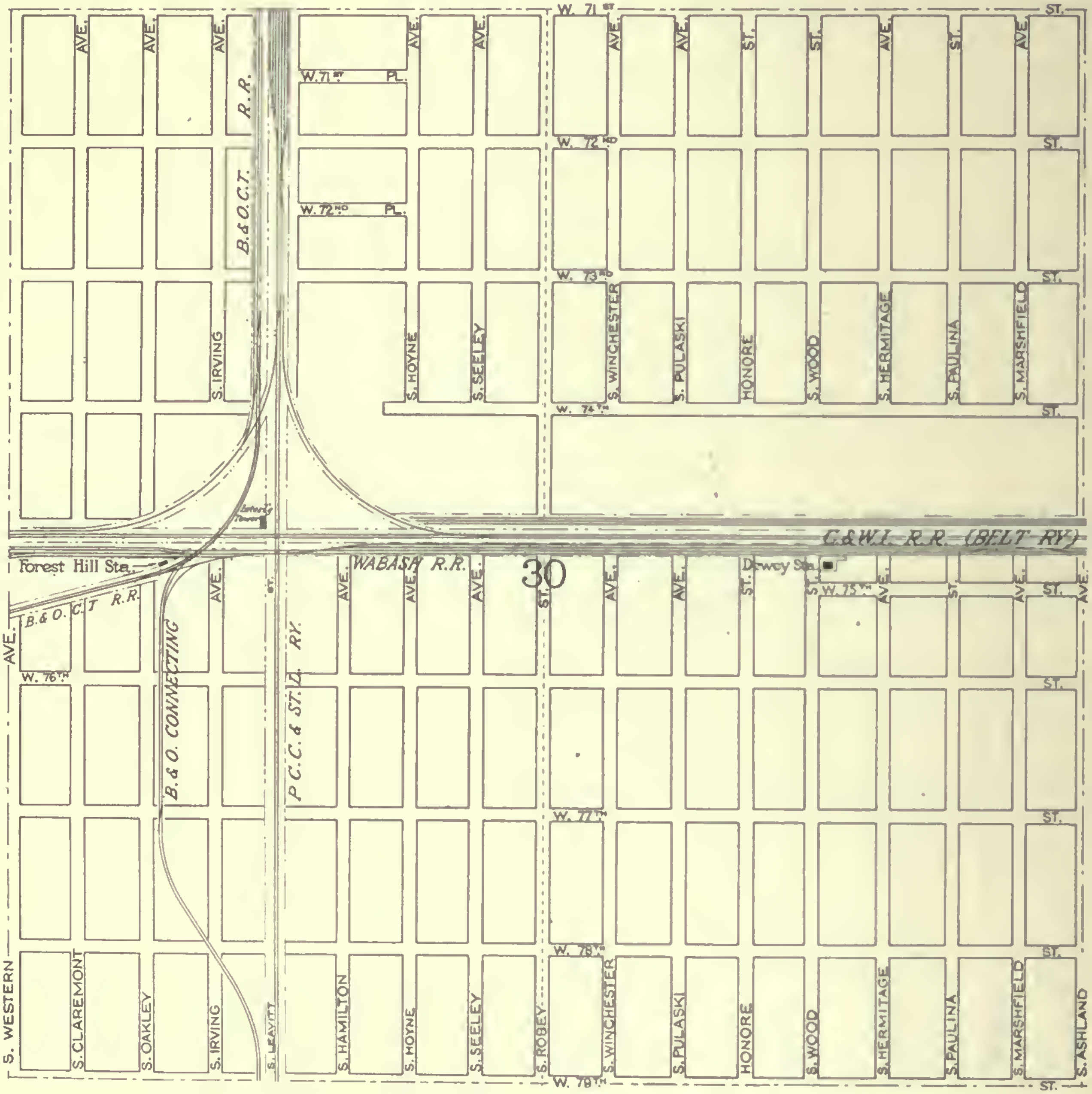

FIG. 203. SECTION MAP, INDEX NO. 109

Section 30 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

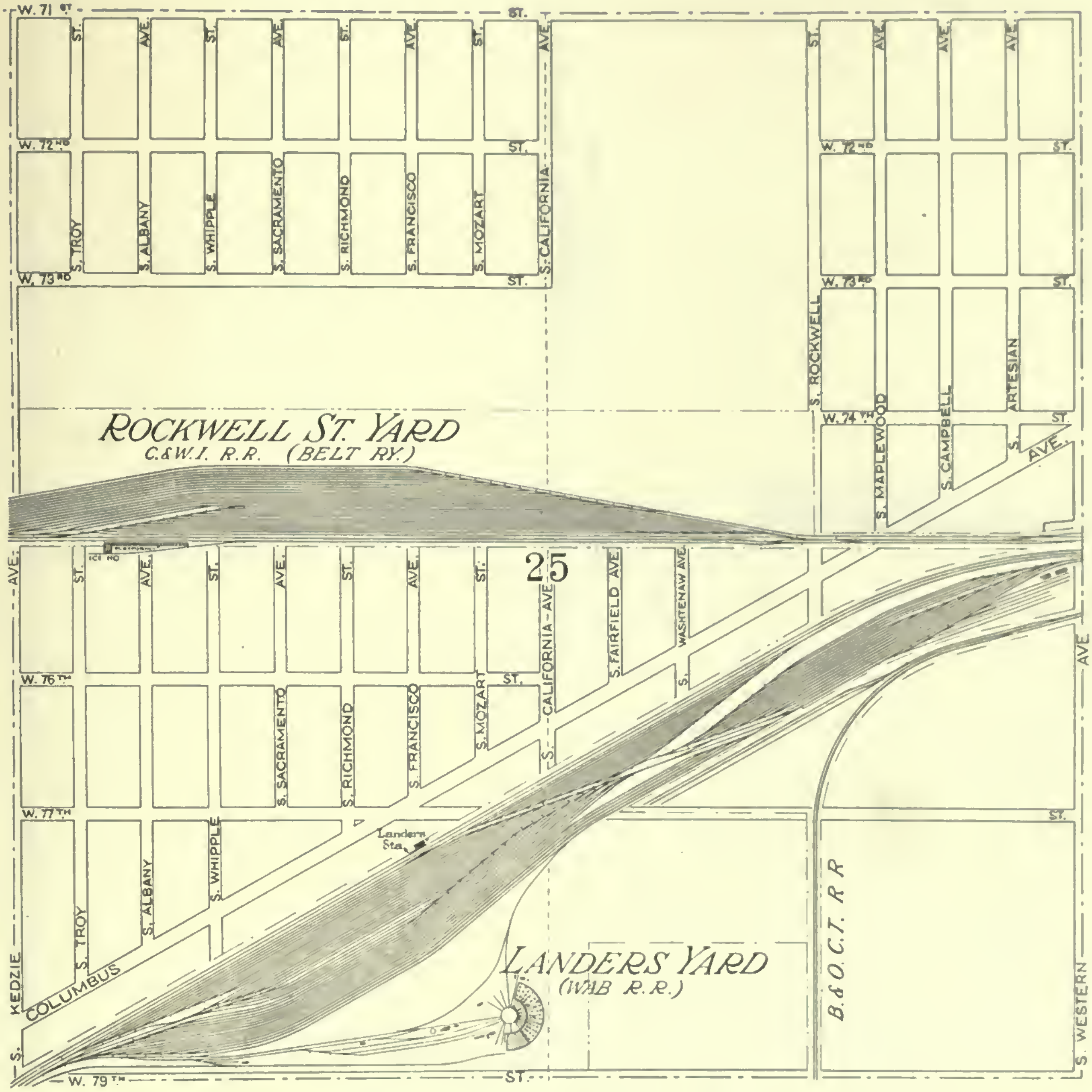

FIG. 204. SECTION MAP, INDEX NO. 110

Section 25 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

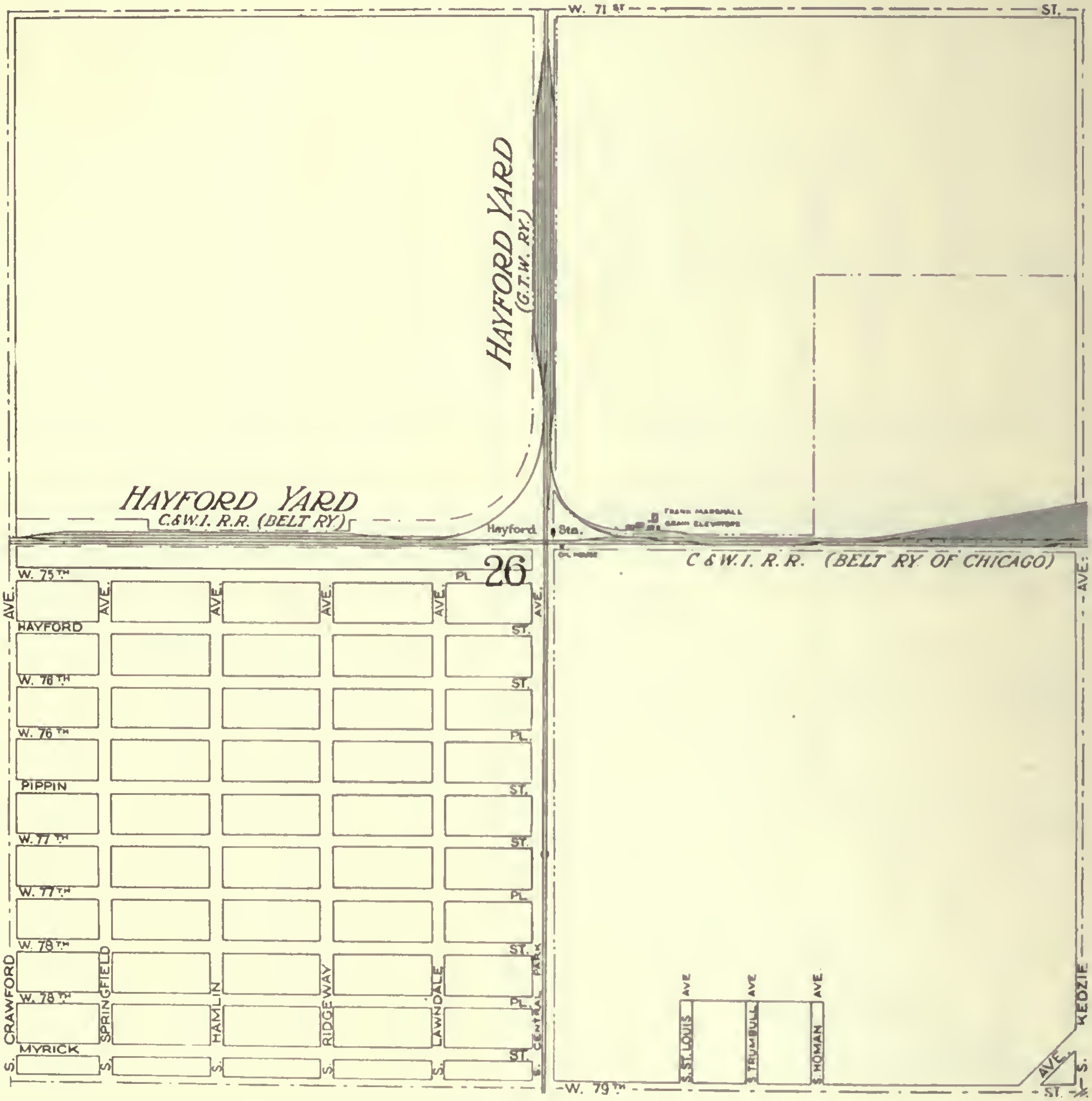

FIG. 205. SECTION MAP, INDEX NO. 111.

Section 26 — Twp. 38 N. — R. 13 E. — 3 P. M Scale: 1″ = 800′

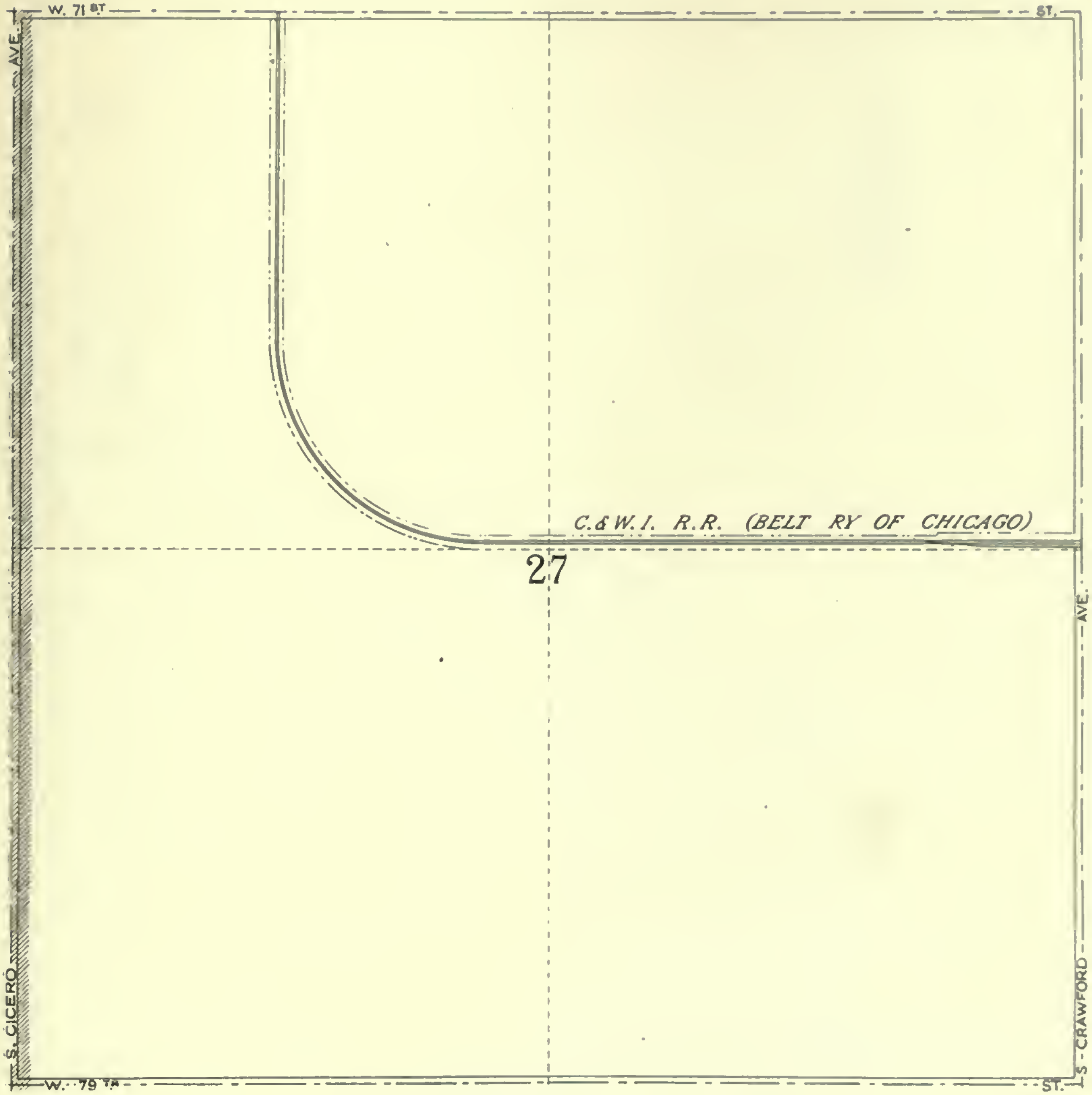

FIG. 206. SECTION MAP, INDEX NO. 112

Section 27 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

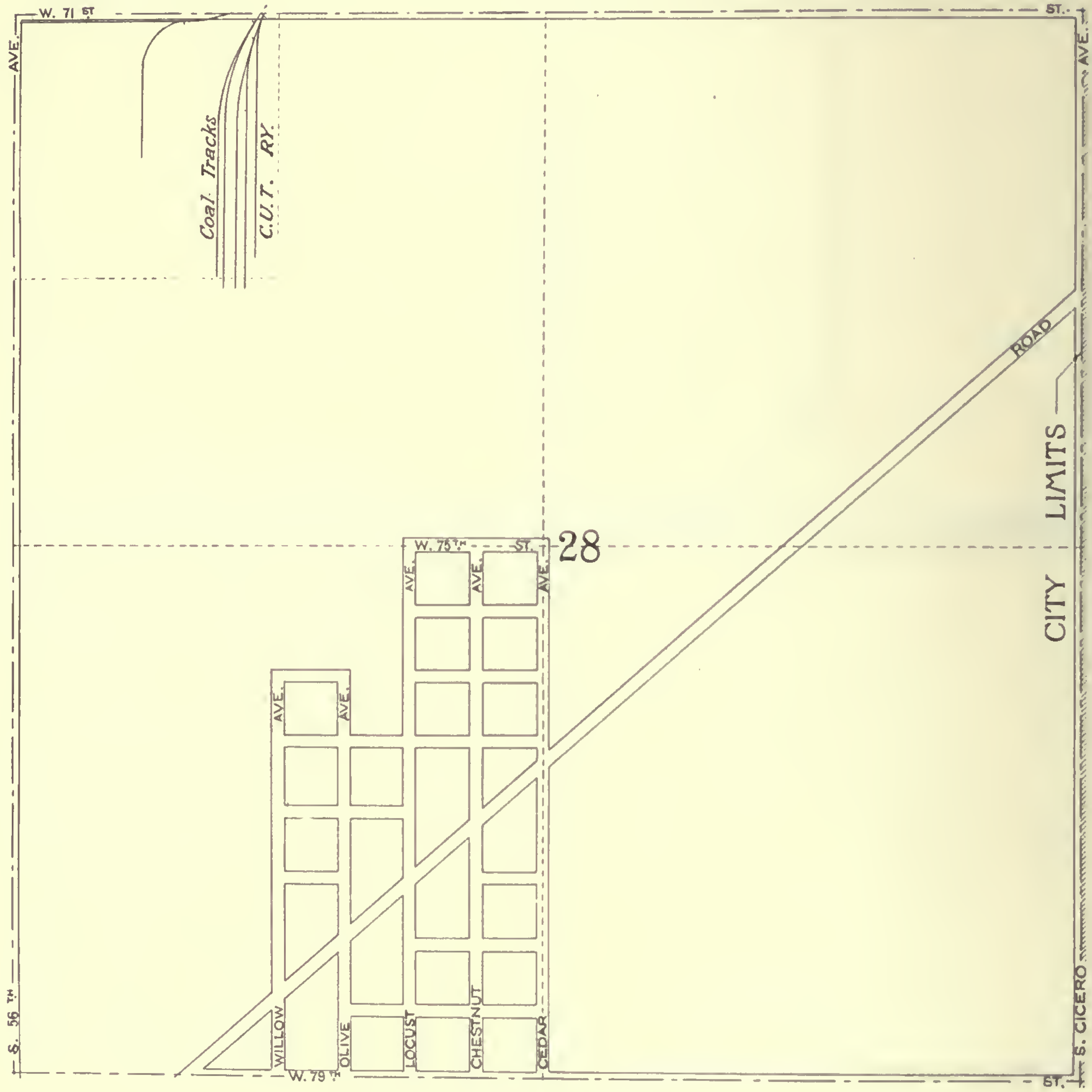

FIG. 207. SECTION MAP, INDEX NO. 113
Section 28 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

FIG. 208. SECTION MAP, INDEX NO. 114

Section 33 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

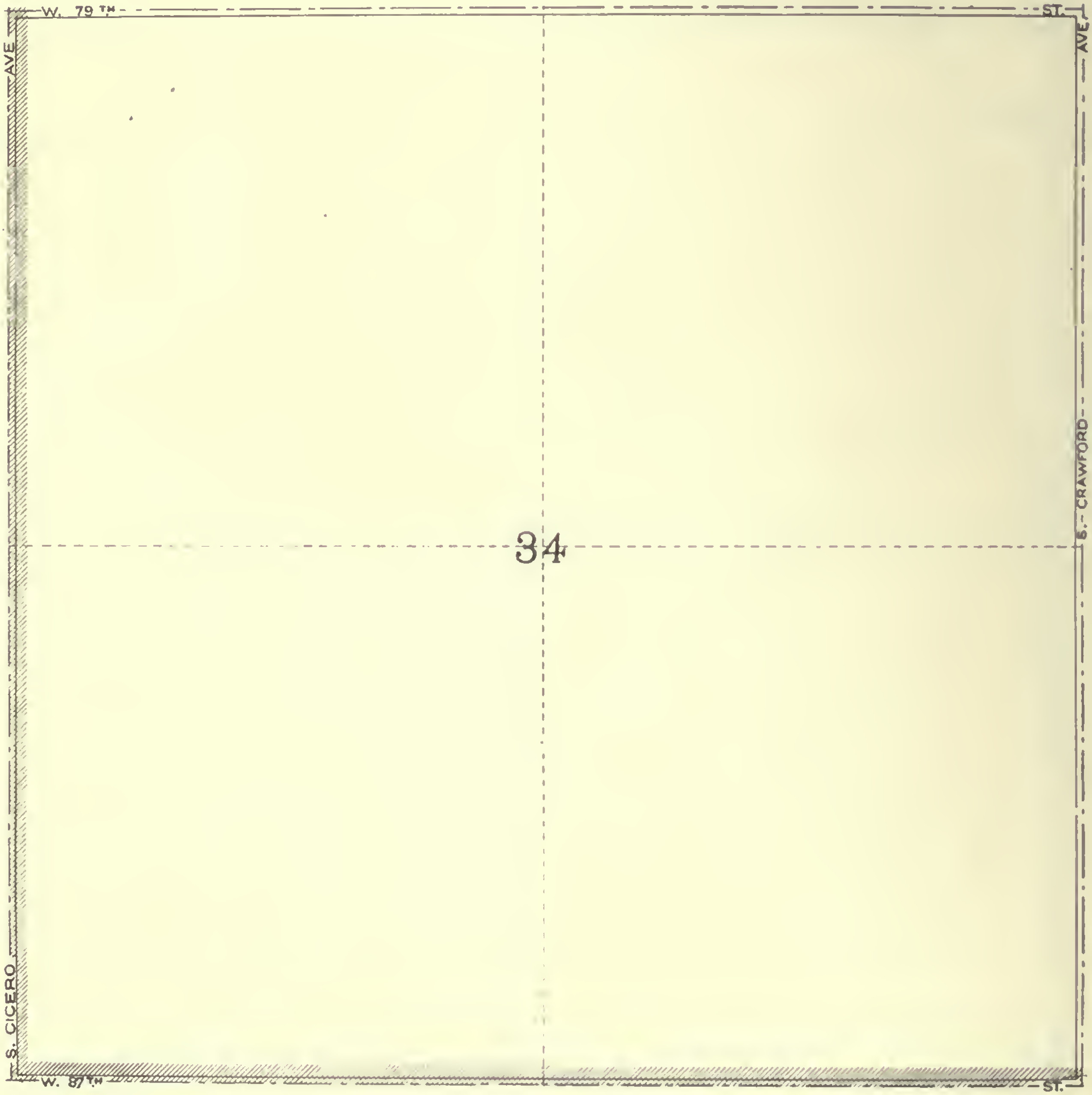

FIG. 209. SECTION MAP, INDEX NO. 115

Section 34 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″=800′

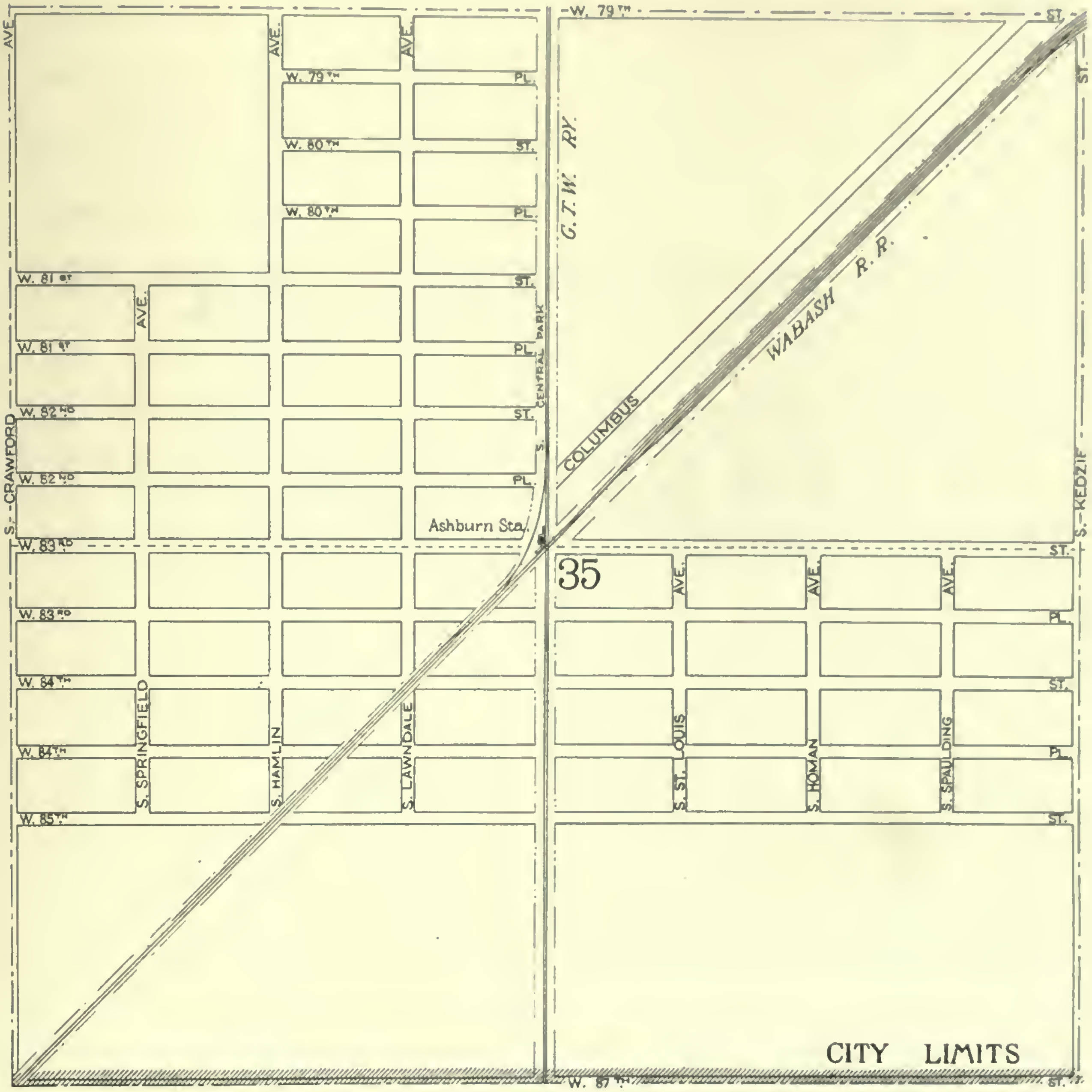

FIG. 210. SECTION MAP, INDEX NO. 116

Section 35 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

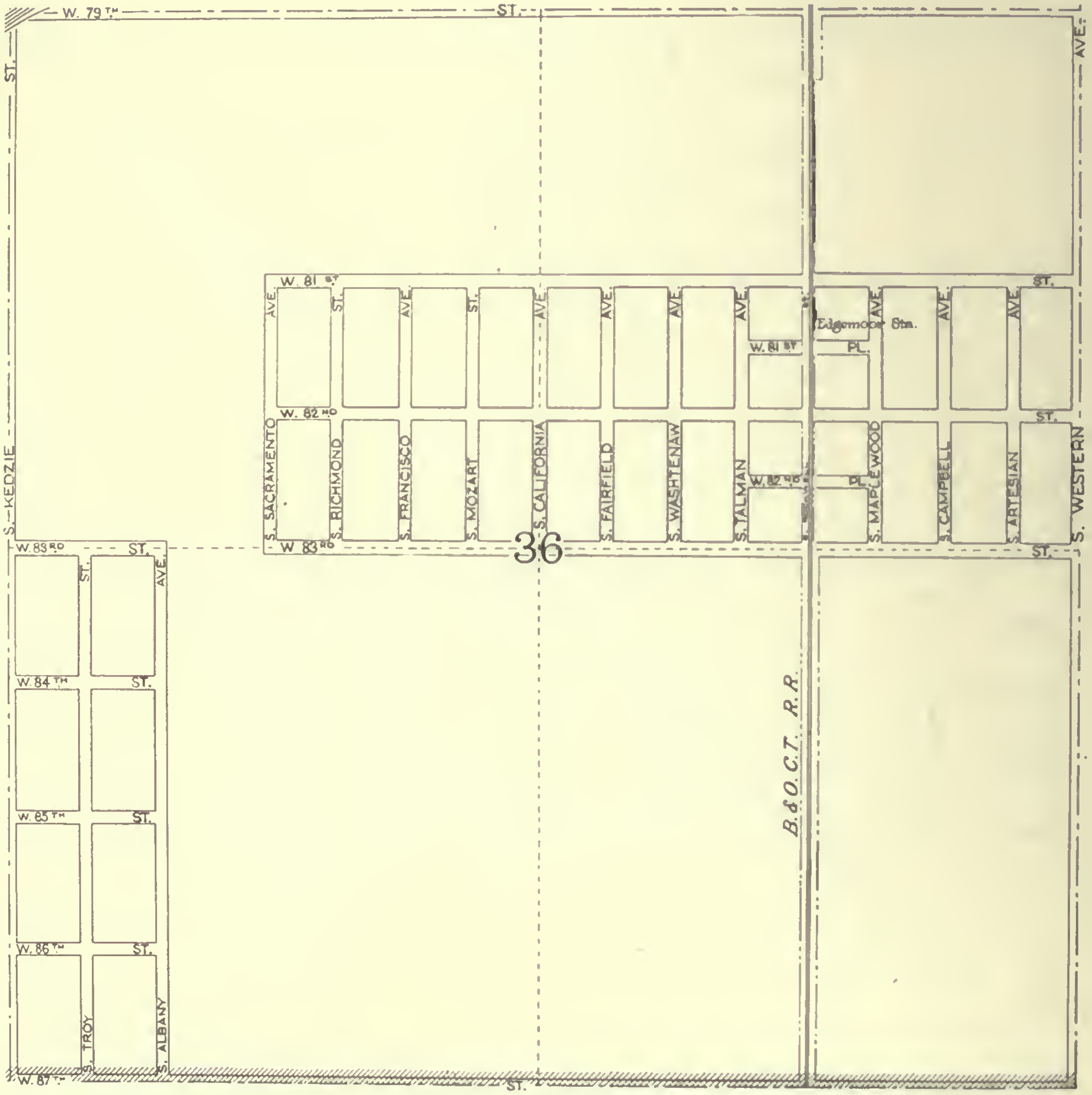

FIG. 211. SECTION MAP, INDEX NO. 117

Section 36 — Twp. 38 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

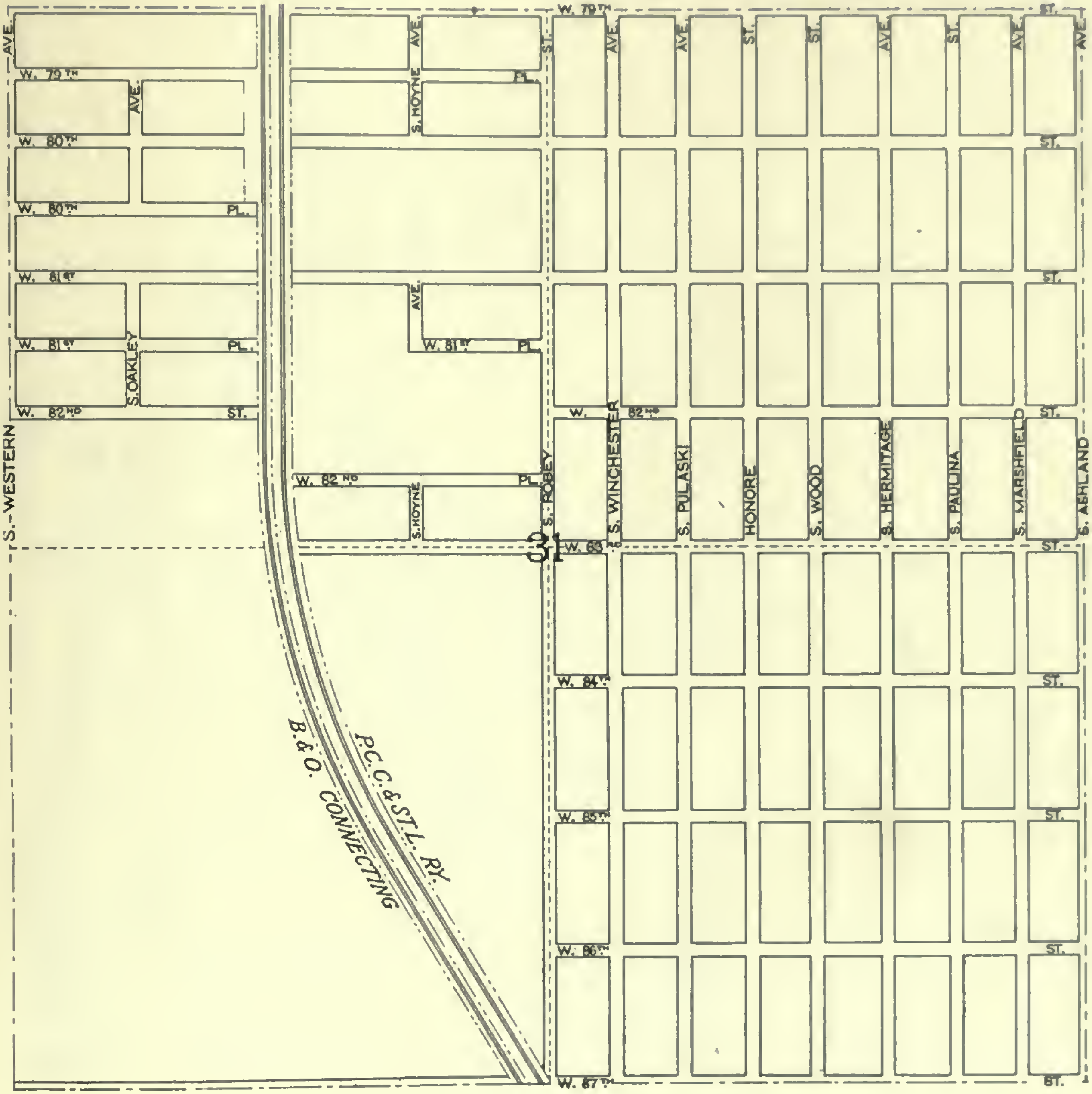

FIG. 212. SECTION MAP, INDEX NO. 118

Section 31 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

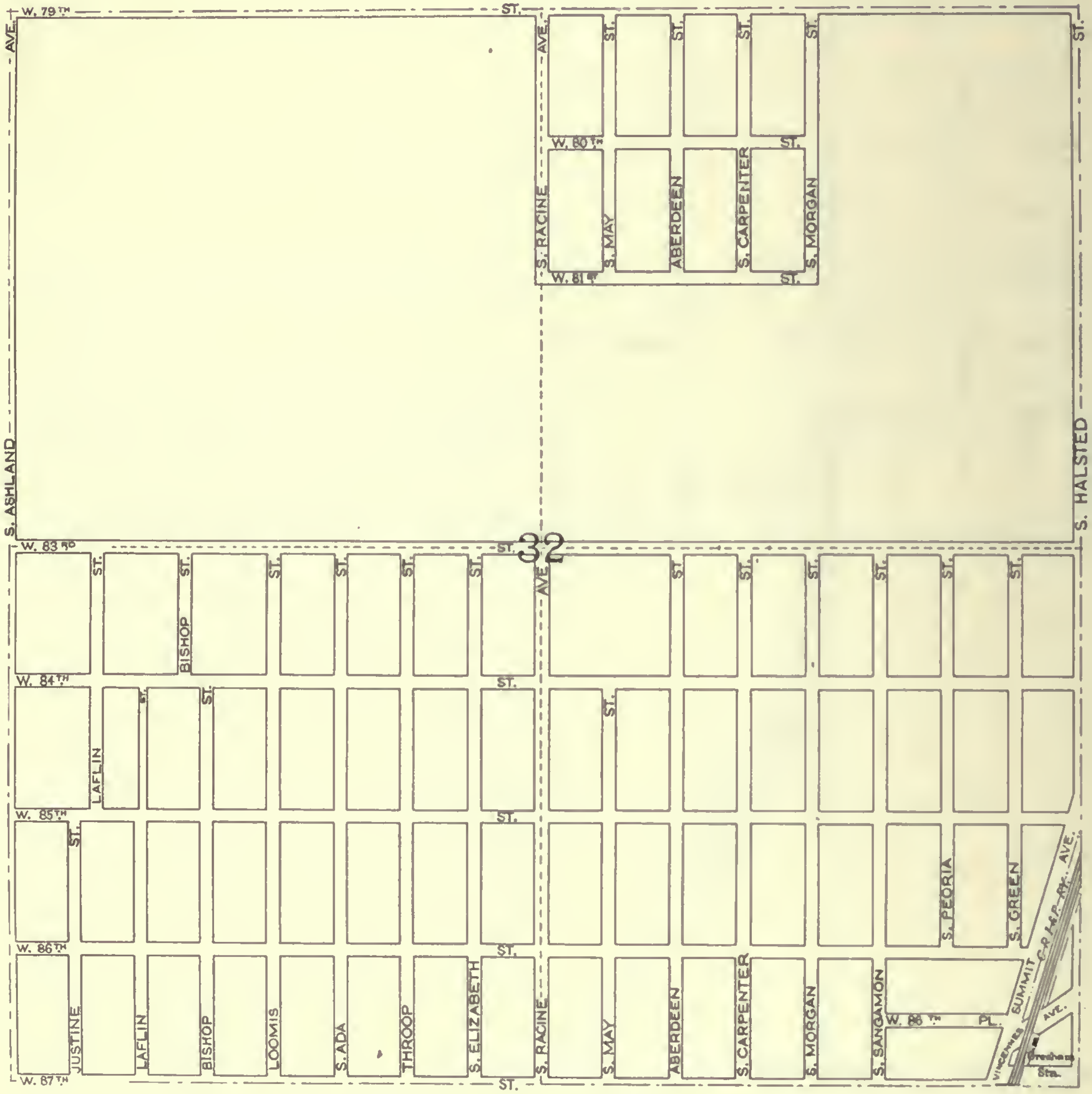

FIG. 213. SECTION MAP, INDEX NO. 119

Section 32 — Twp. 38 N.— R. 14 E.— 3 P. M. Scale: 1″ = 800′

FIG. 214. SECTION MAP, INDEX NO. 120

Section 33 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1" = 800'

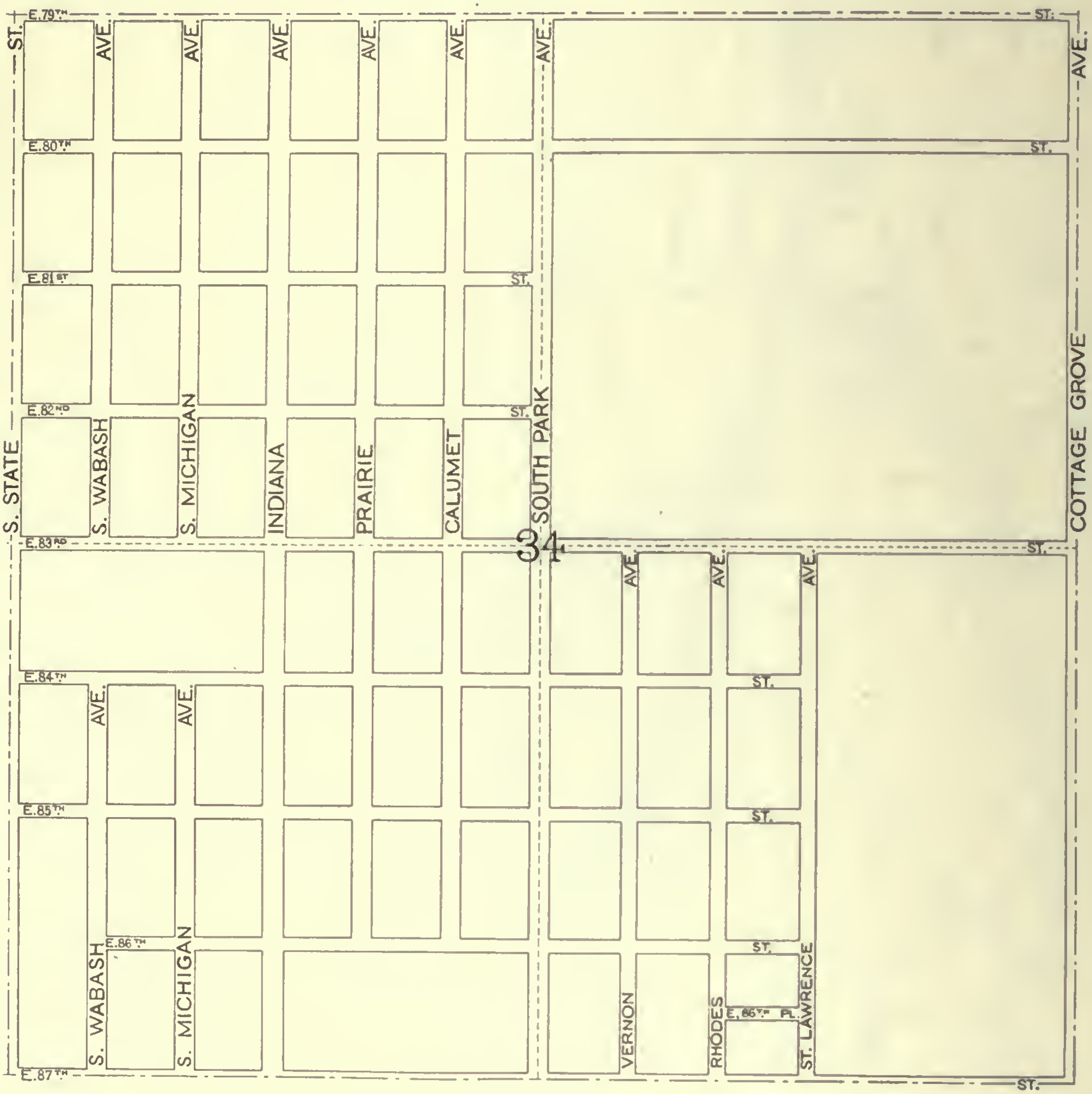

FIG. 215. SECTION MAP, INDEX NO. 121

Section 34 — Twp. 38 N.— R. 14 E.— 3 P. M. Scale: 1" = 800'

FIG. 216. SECTION MAP, INDEX NO. 122

Section 35 — Twp. 38 N. — R. 14 E. —3 P. M. Scale: 1″ = 800′

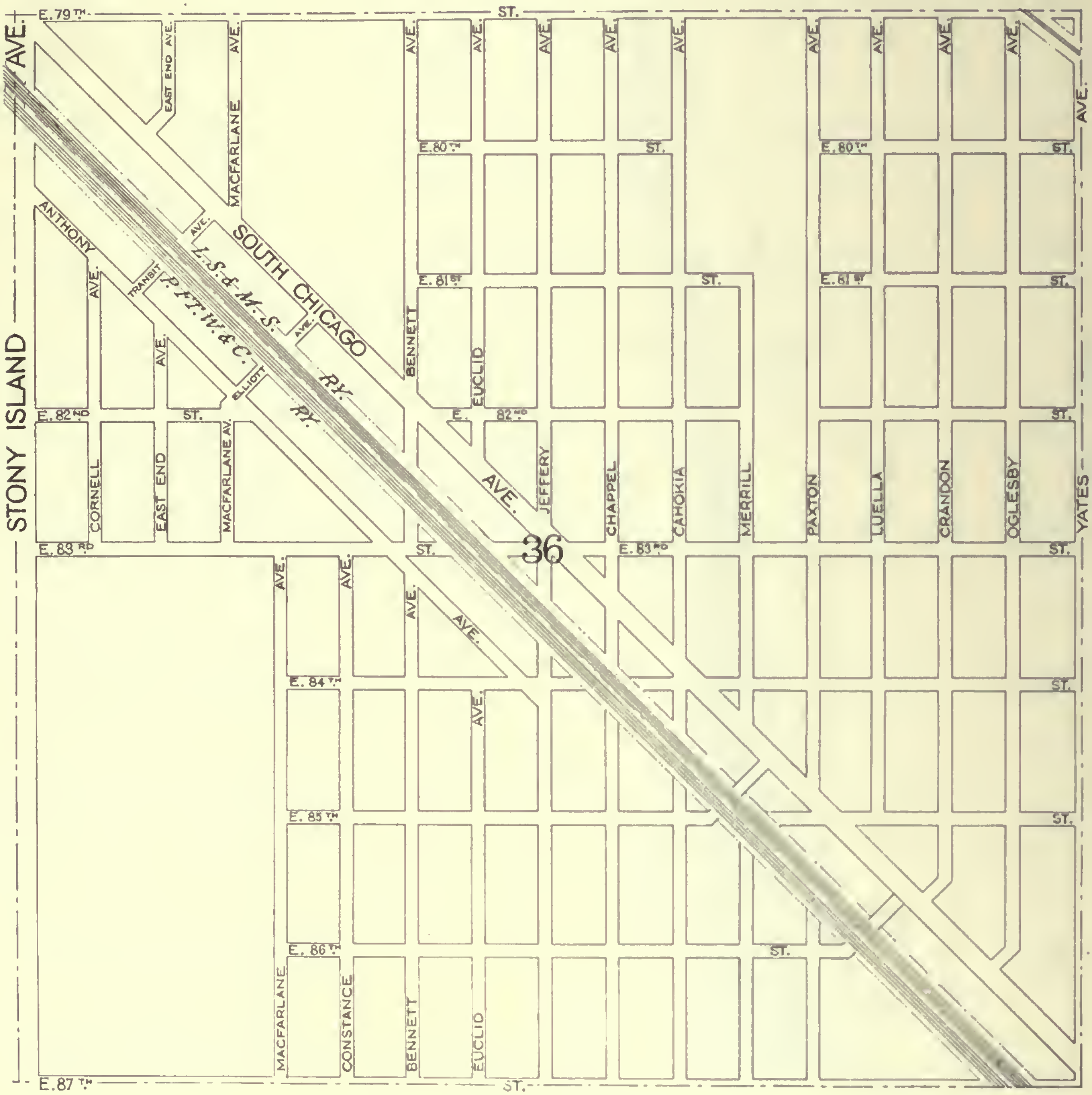

FIG. 217. SECTION MAP, INDEX NO. 123

Section 36 — Twp. 38 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

FIG. 218. SECTION MAP, INDEX NO. 124

Section 31 — Twp. 38 N. — R. 15 E. — 3 P. M. Scale: 1″ = 800′

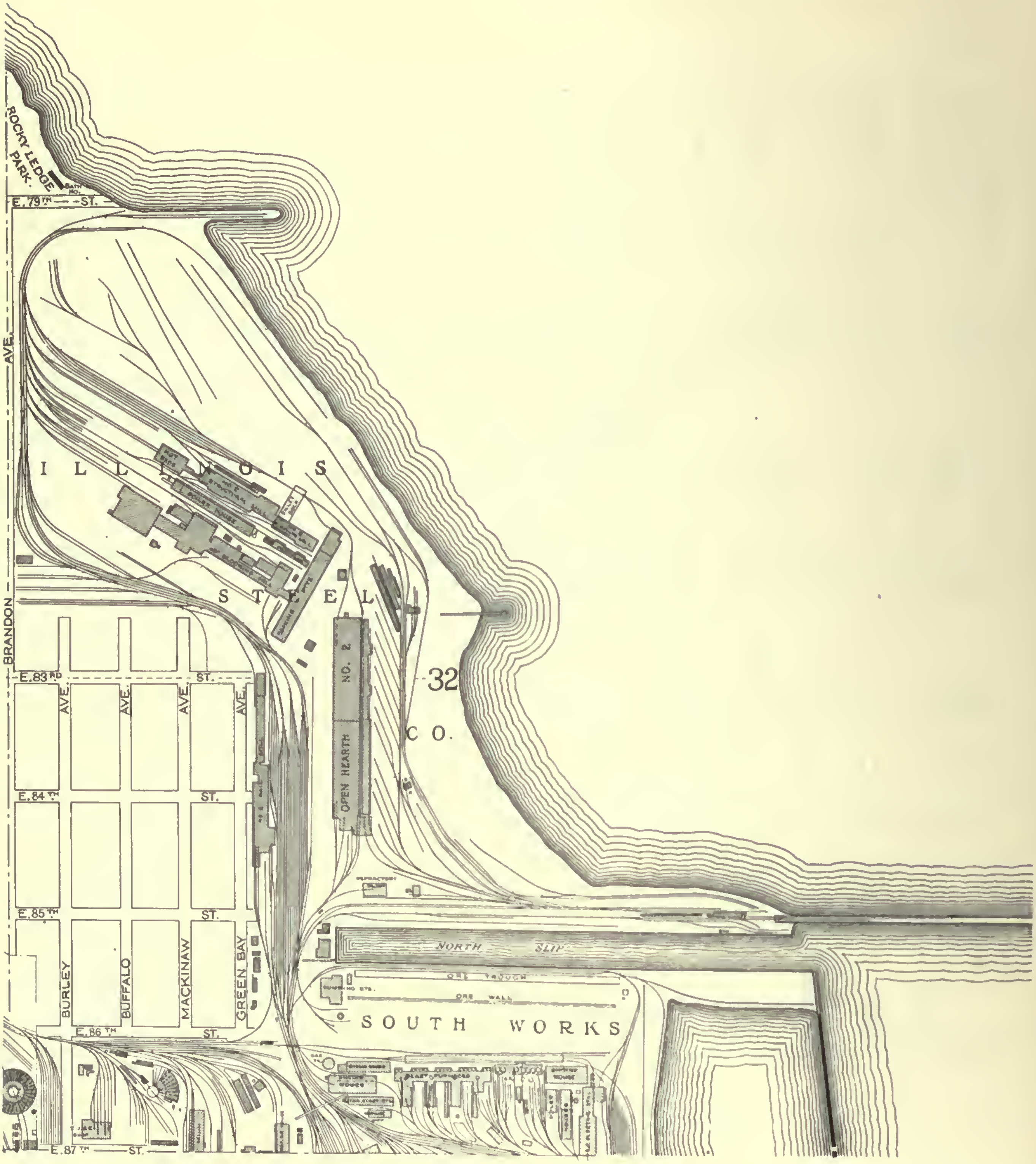

FIG. 219. SECTION MAP, INDEX NO. 125
Fractional Section 32 — Twp. 38 N. — R. 15 E. — 3 P. M. Scale: 1" = 800'

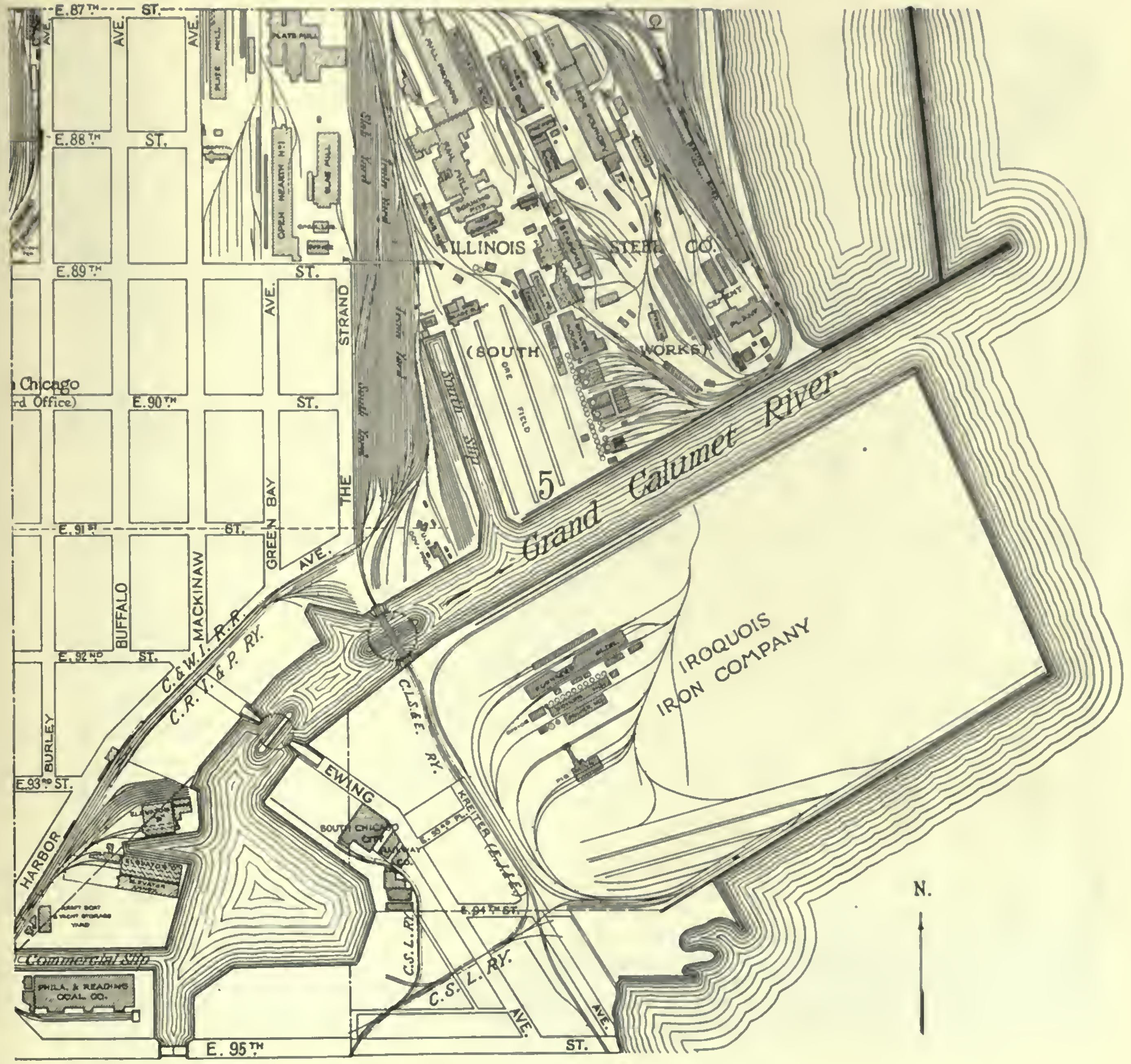

FIG. 220. SECTION MAP, INDEX NO. 126

Fractional Section 5 — Twp. 37 N. — R. 15 E. — 3 P. M. Scale: 1" = 800'

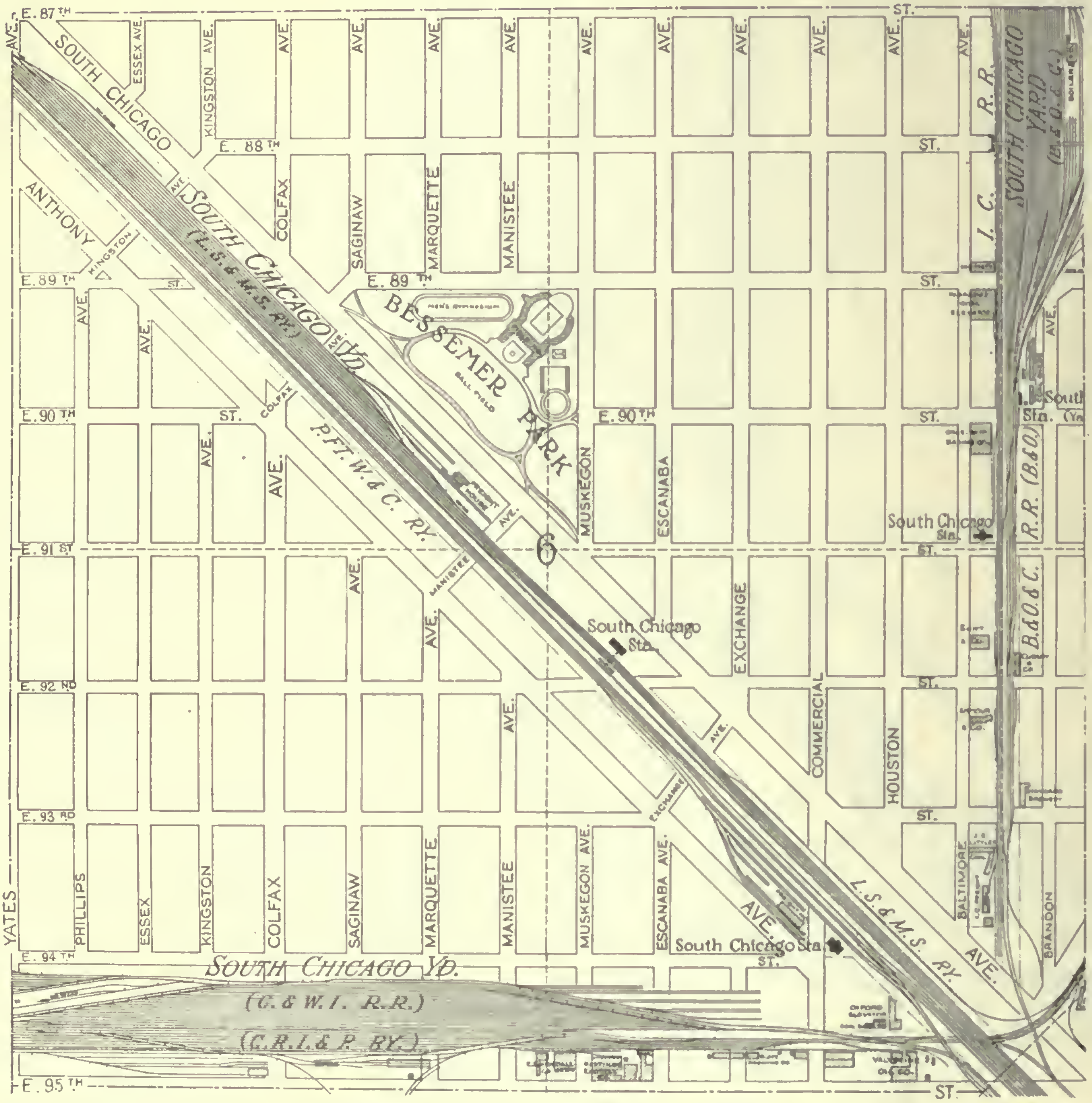

FIG. 221. SECTION MAP, INDEX NO. 127

Section 6 — Twp. 37 N. — R. 15 E. — 3 P. M. Scale: 1″ = 800′

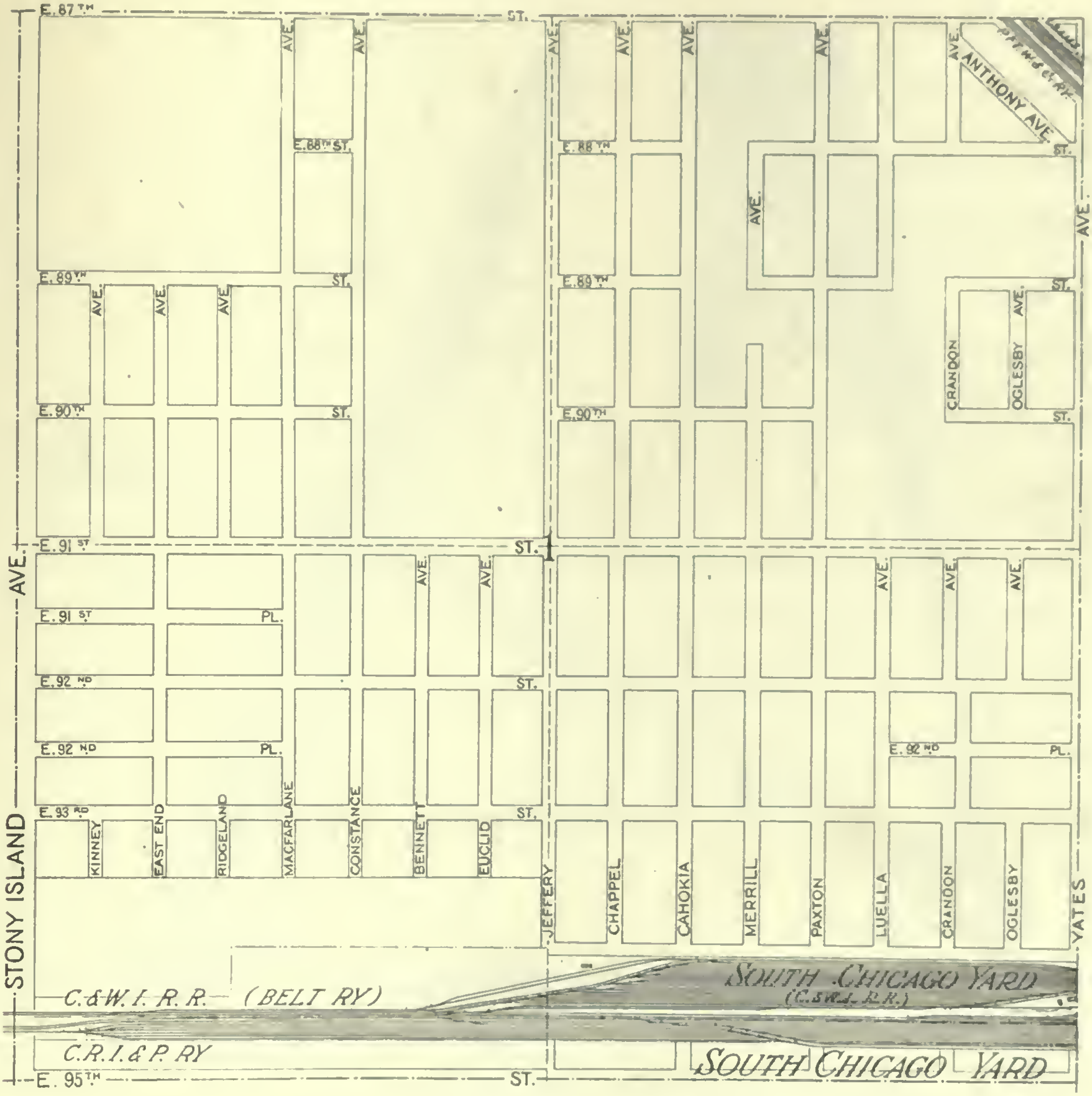

FIG. 222. SECTION MAP, INDEX NO. 128

Section 1 — Twp. 37 N. — R. 14 E. — 3 P. M. Scale: 1″=800′

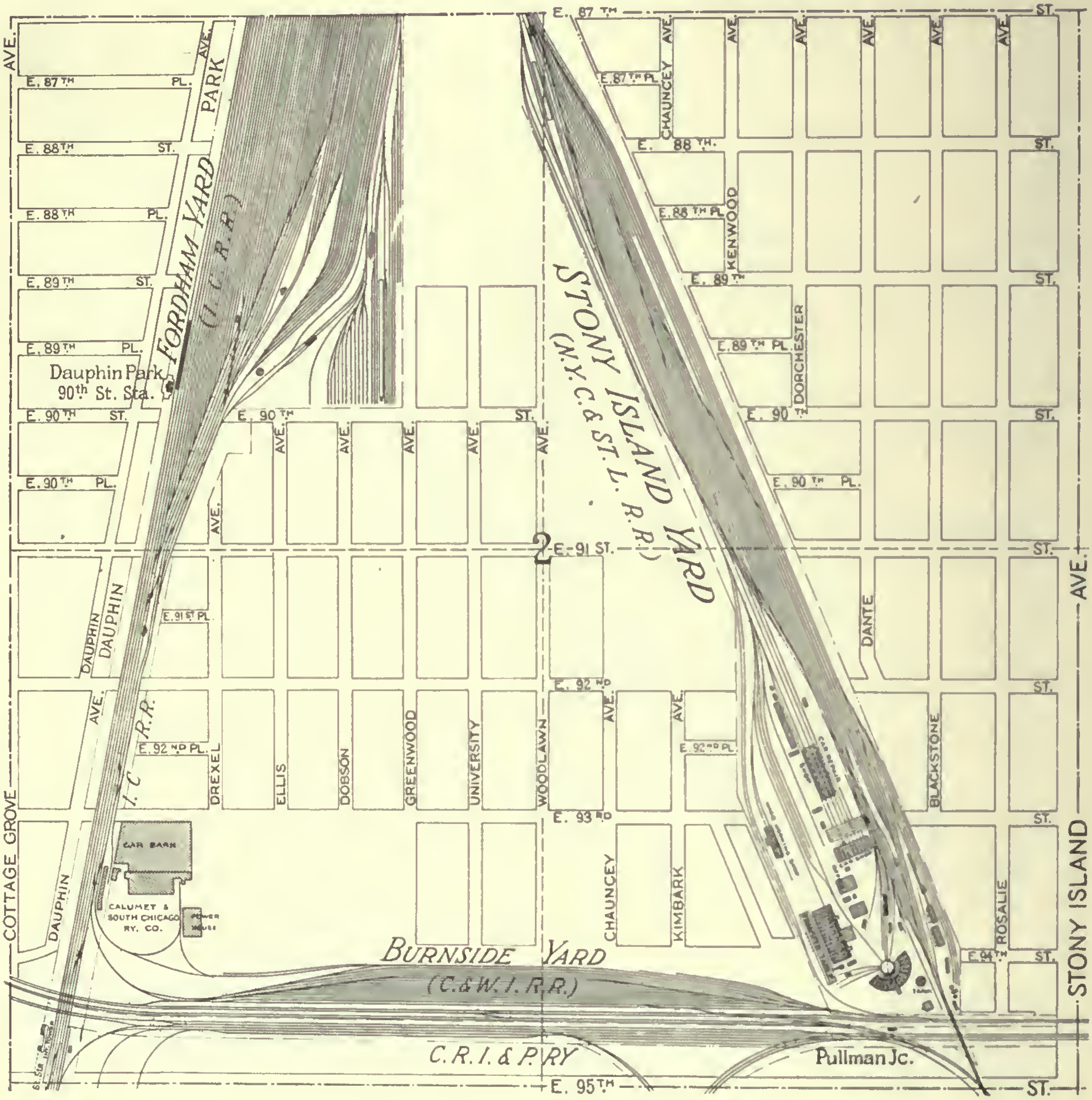

FIG. 223. SECTION MAP, INDEX NO. 129

Section 2 — Twp. 37 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

FIG. 224. SECTION MAP, INDEX NO. 130

Section 3 — Twp. 37 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

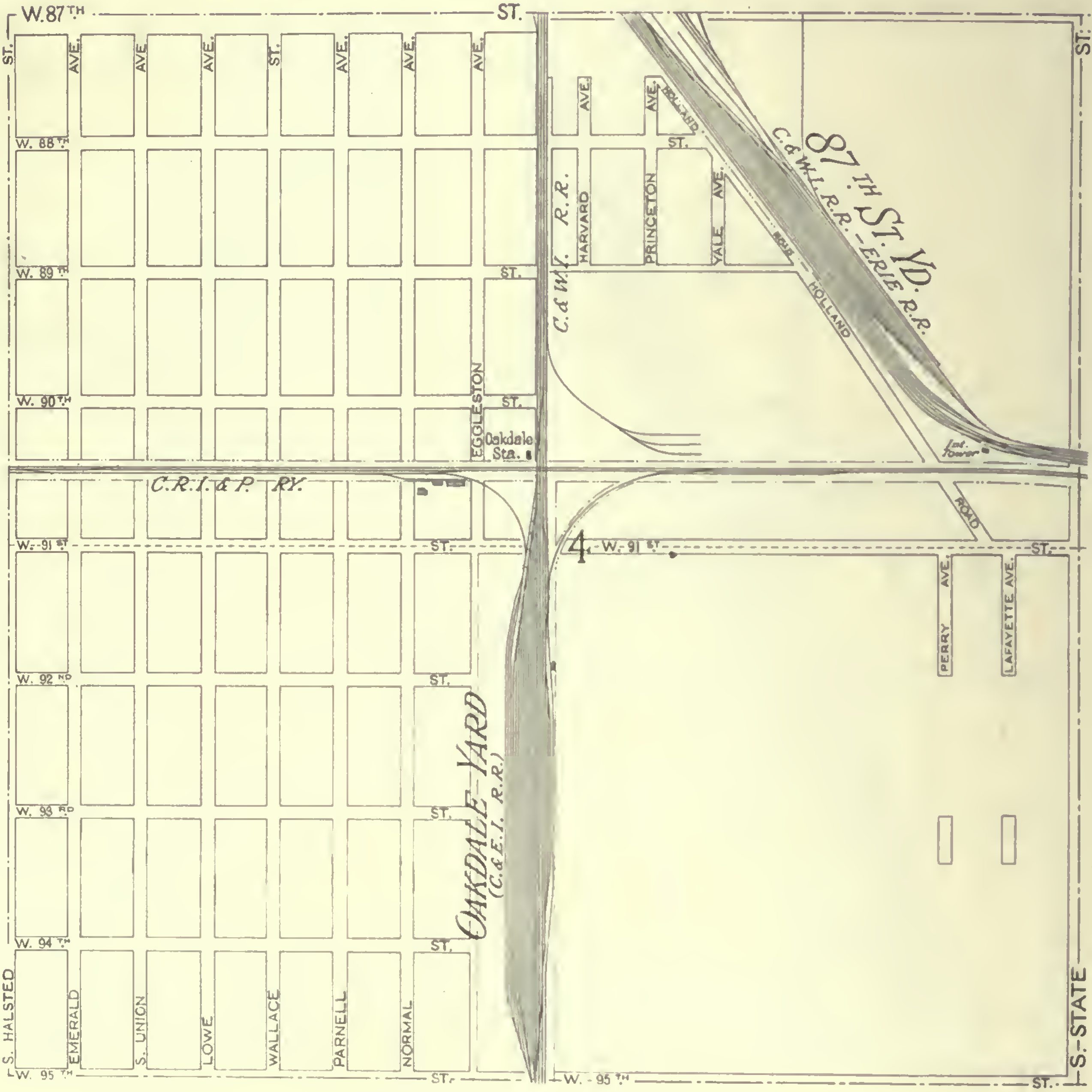

FIG. 225. SECTION MAP, INDEX NO. 131

Section 4 — Twp. 37 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

FIG. 226. SECTION MAP, INDEX NO. 132

Section 5 — Twp. 37 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

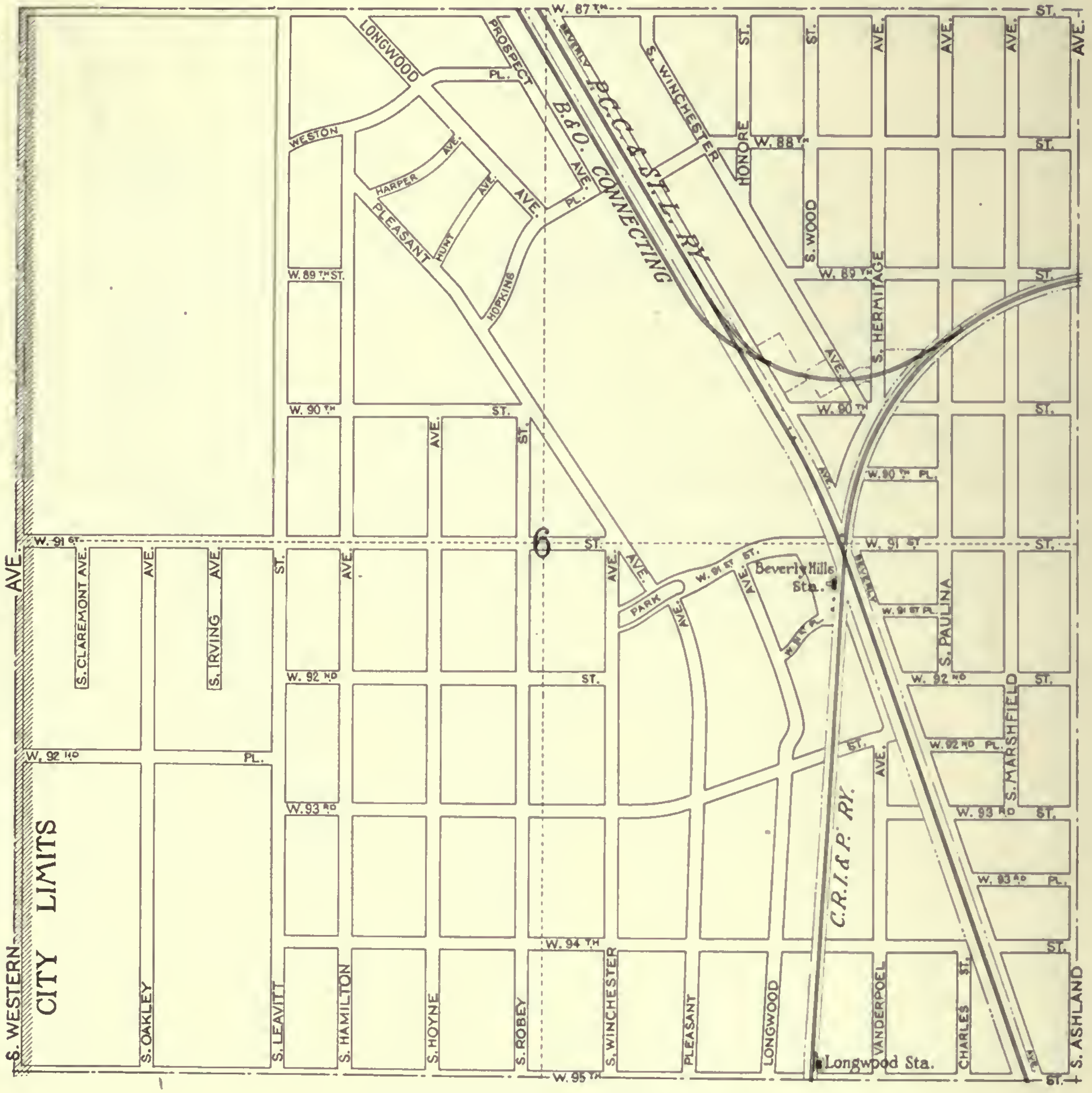

FIG. 227. SECTION MAP, INDEX NO. 133

Section 6 — Twp. 37 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

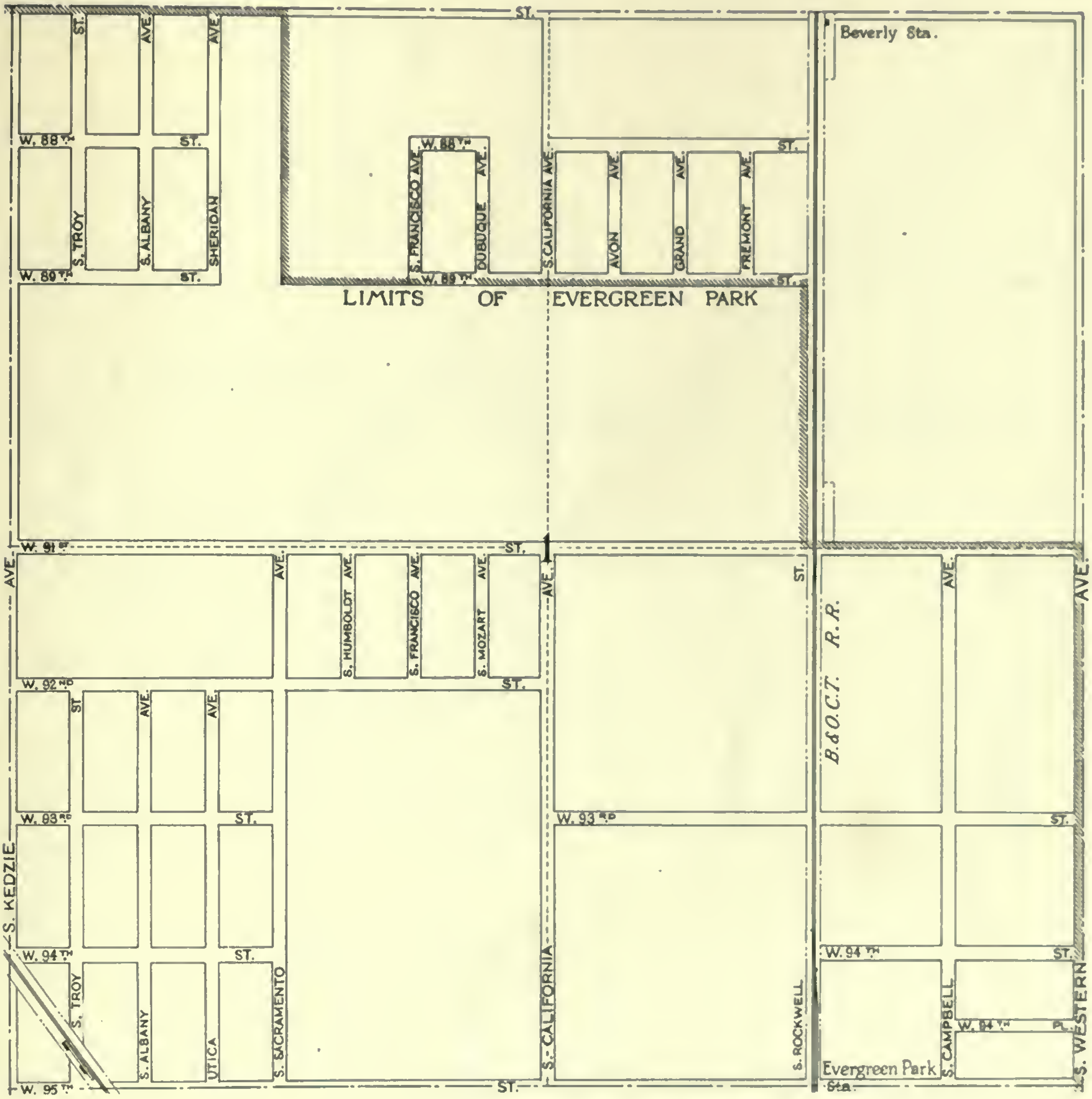

FIG. 228. SECTION MAP, INDEX NO. 134

Section 1 — Twp. 37 N. — R. 13 E. — 3 P. M. Scale: 1″=800′

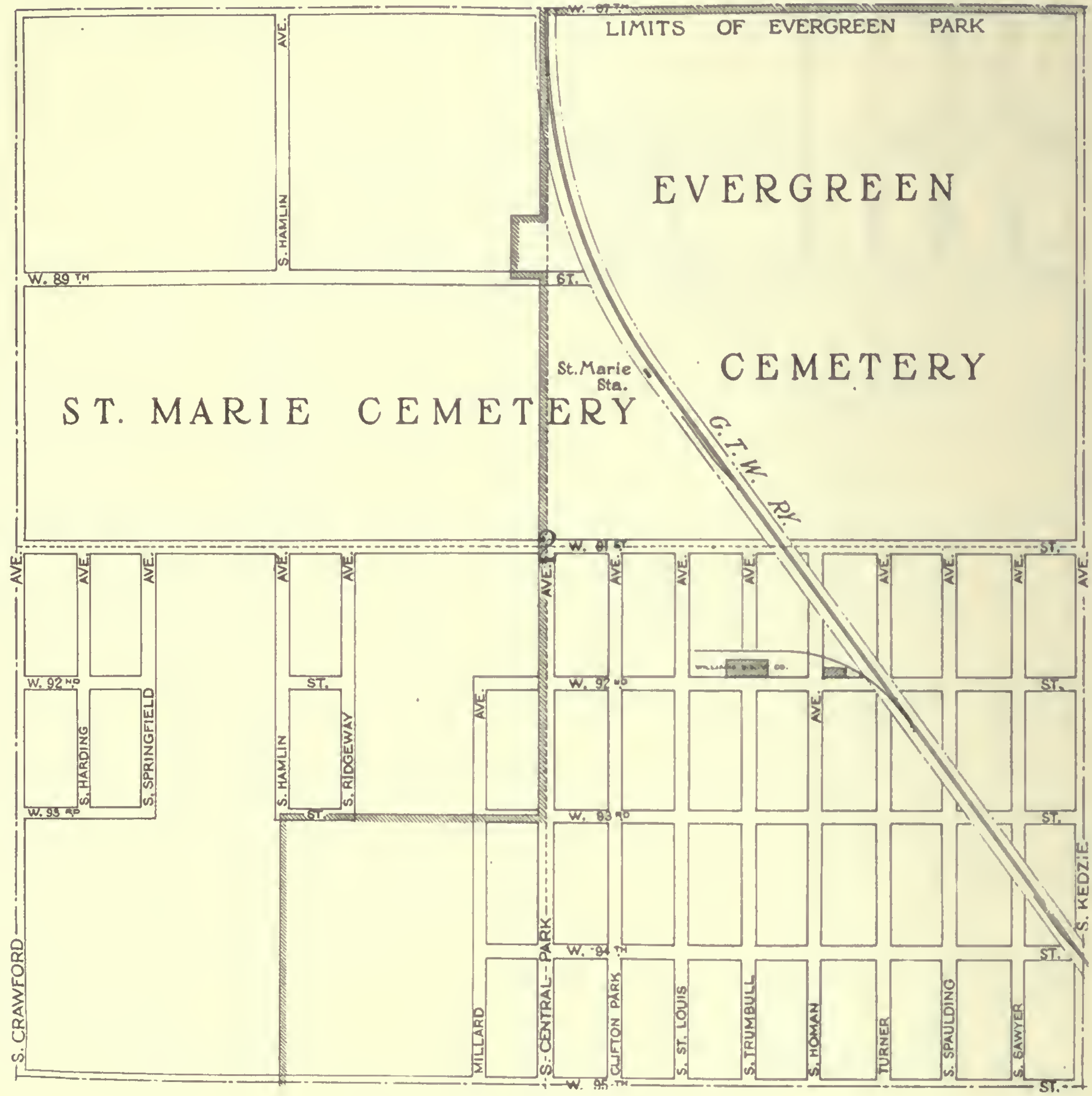

FIG. 229. SECTION MAP, INDEX NO. 135
Section 2 — Twp. 37 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

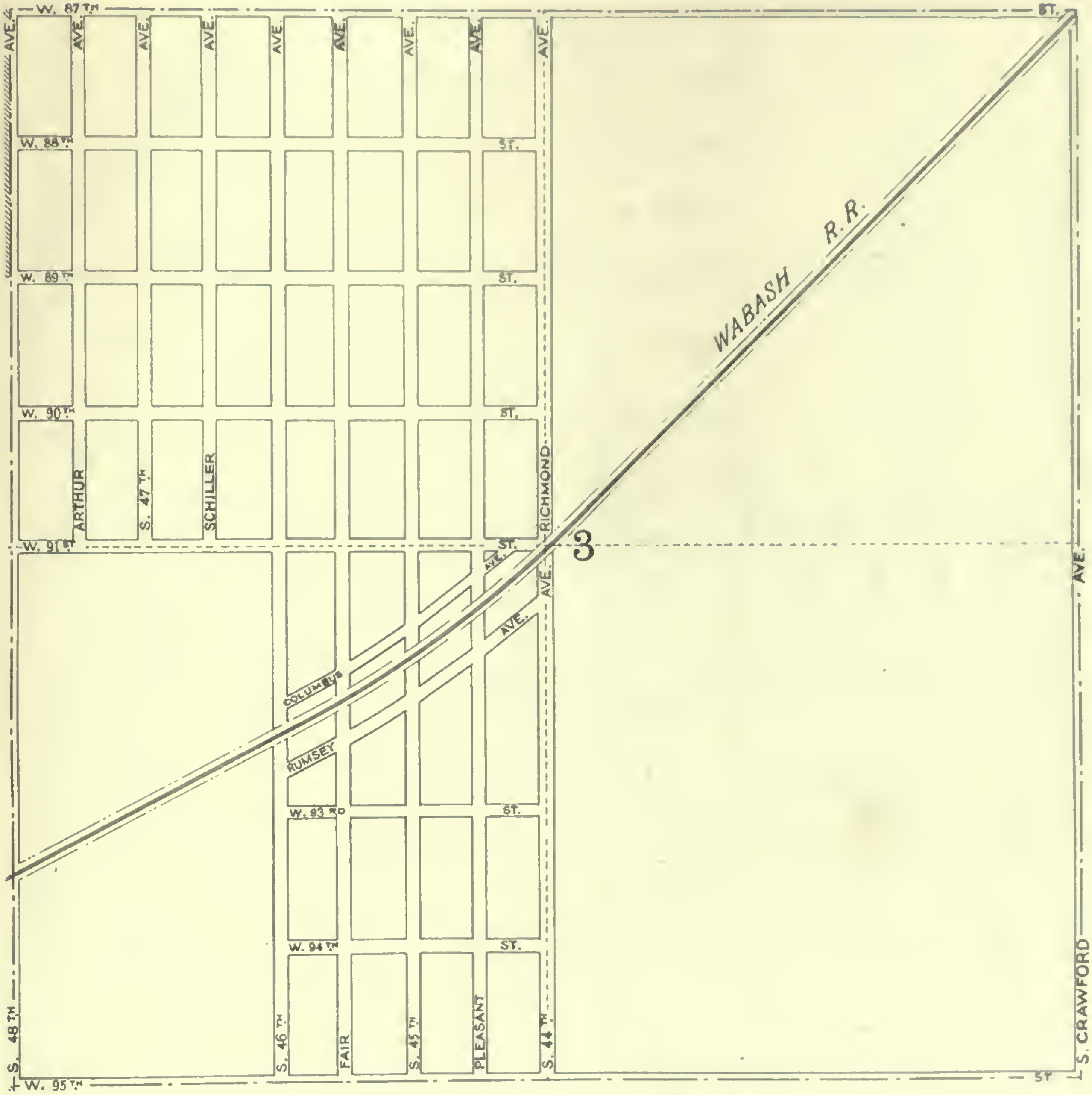

FIG. 230. SECTION MAP, INDEX NO. 136

Section 3 — Twp. 37 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

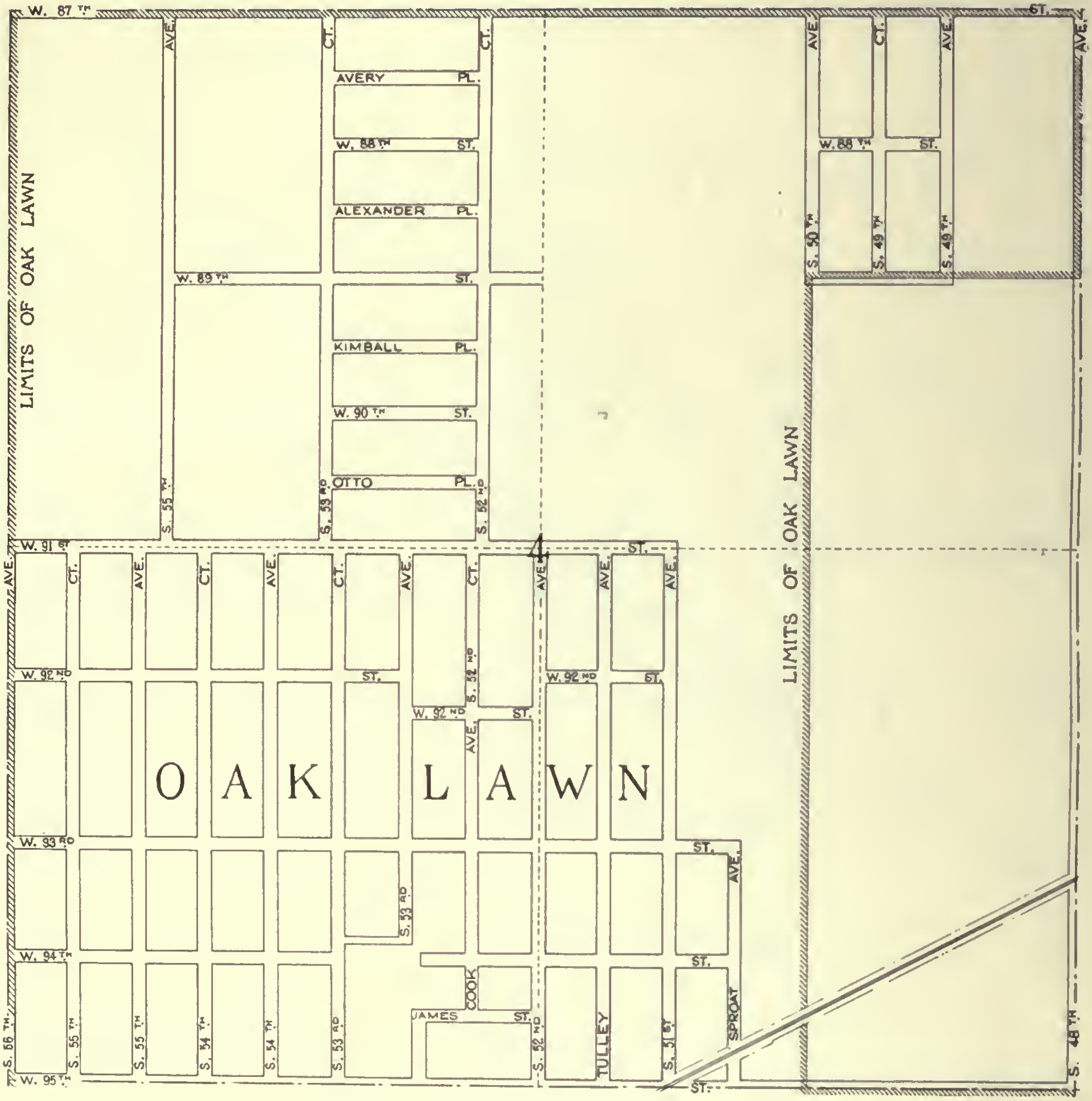

FIG. 231. SECTION MAP, INDEX NO. 137

Section 4 — Twp. 37 N.— R. 13 E.— 3 P. M. Scale: 1″ = 800′

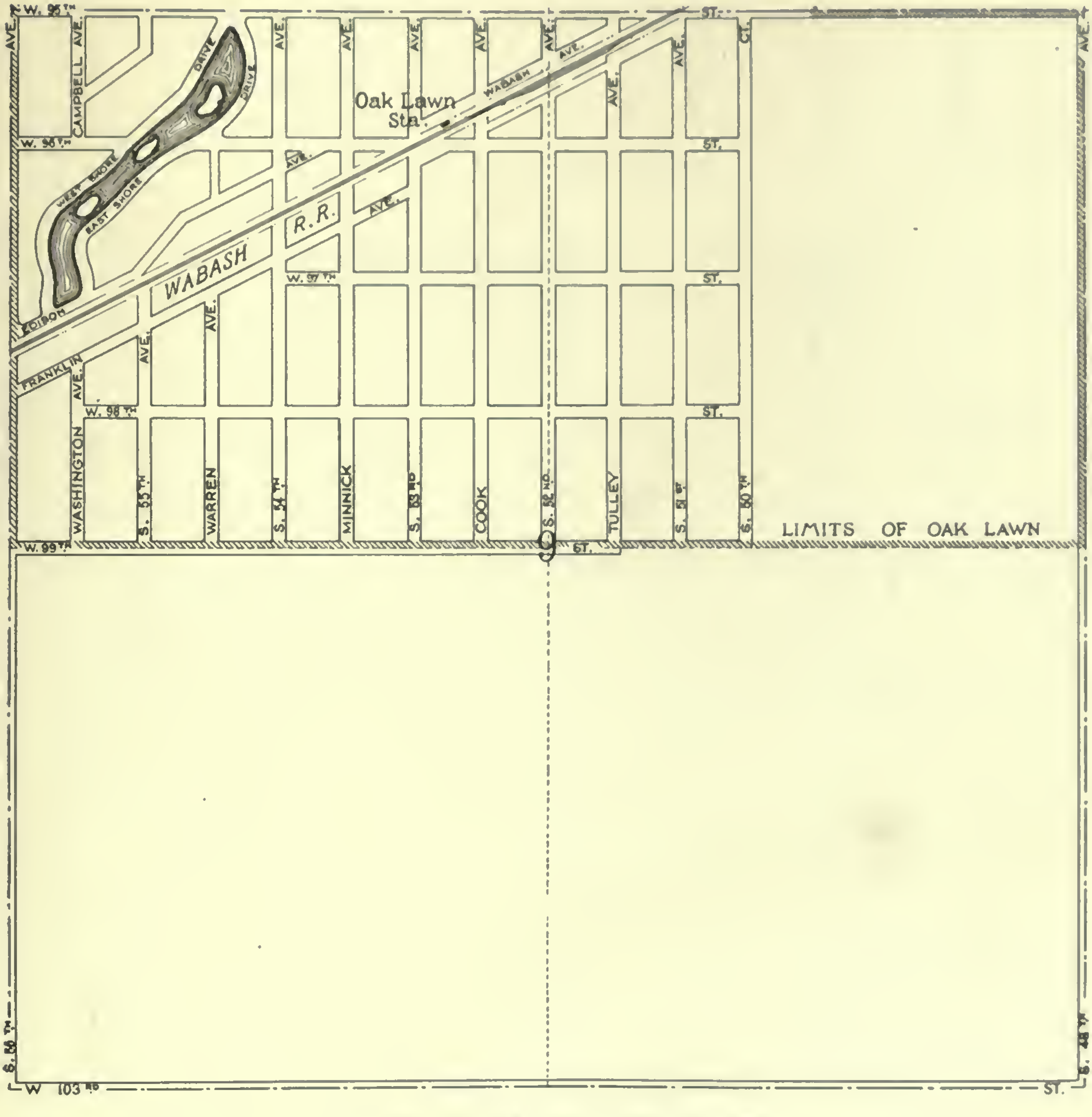

FIG. 232. SECTION MAP, INDEX NO. 138

Section 9 — Twp. 37 N.— R. 13 E.— 3 P. M. Scale: 1″ = 800′

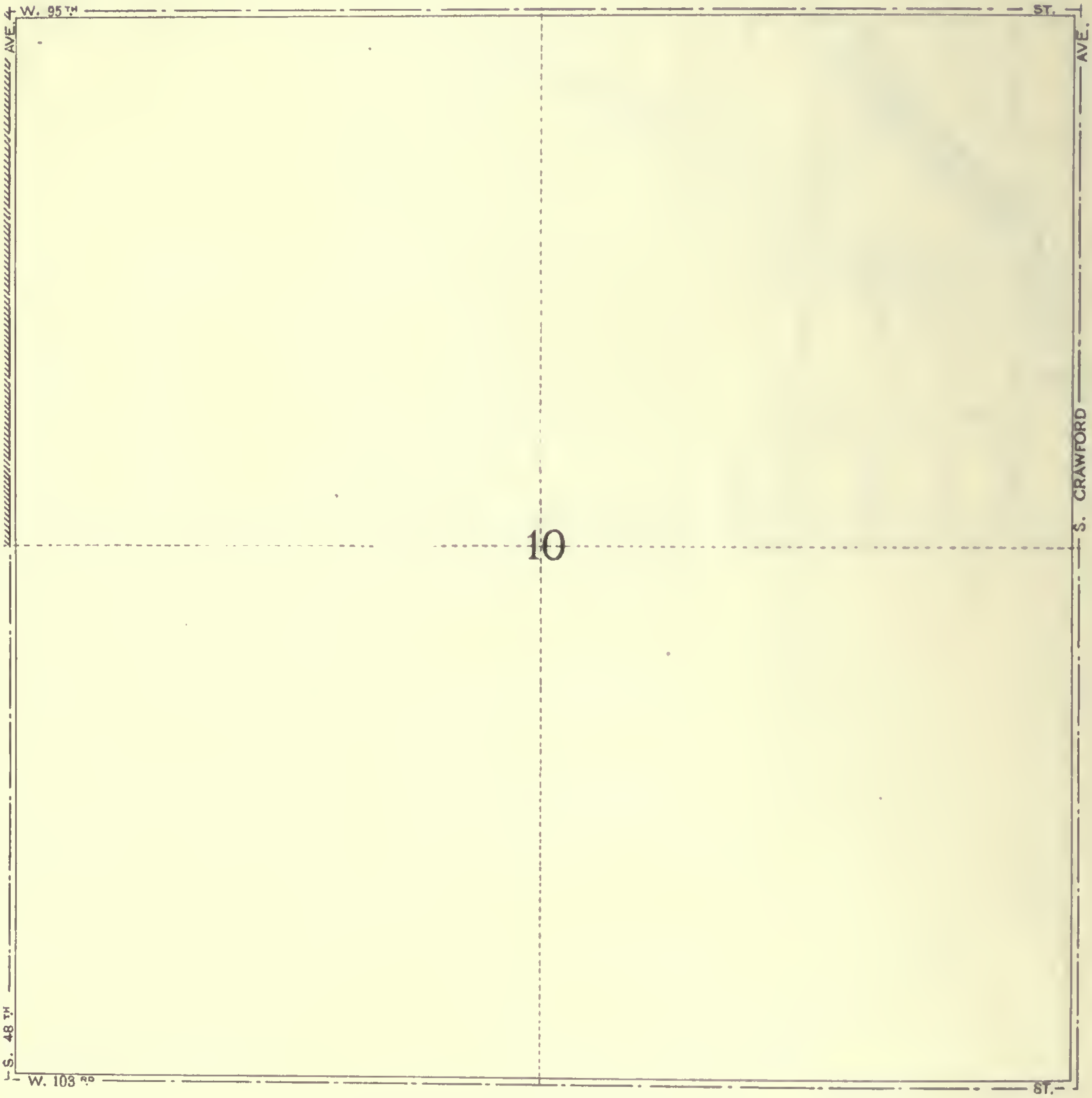

FIG. 233. SECTION MAP, INDEX NO. 139

Section 10 — Twp. 37 N.—R. 13 E.— 3 P. M. Scale: 1″ = 800′

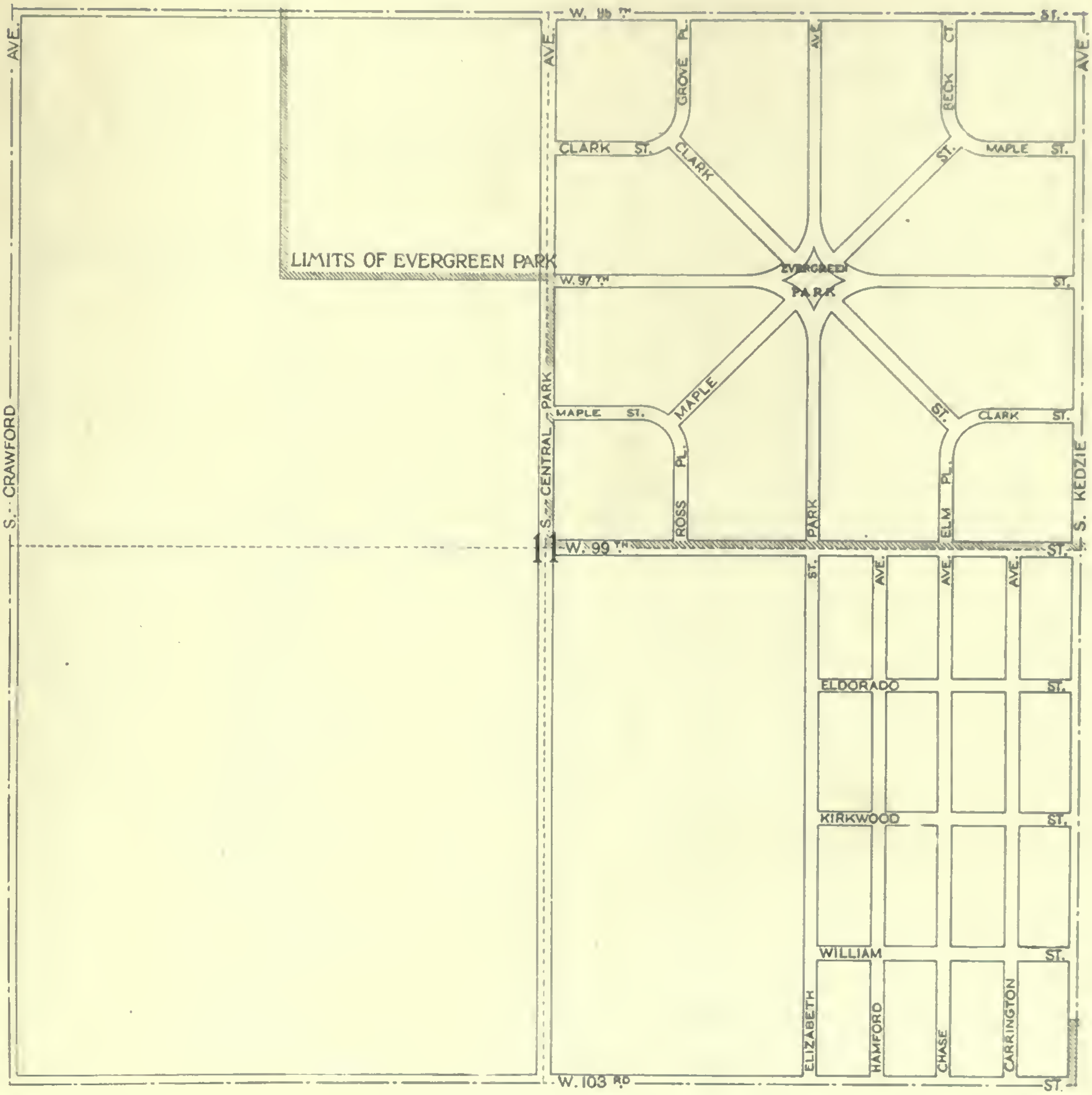

FIG. 234. SECTION MAP, INDEX NO. 140

Section 11 — Twp. 37 N. — R. 13 E. — 3 P. M. Scale: 1″ = 800′

FIG. 235. SECTION MAP, INDEX NO. 141
Section 12—Twp. 37 N.—R. 13 E.—3 P. M. Scale: 1″=800′

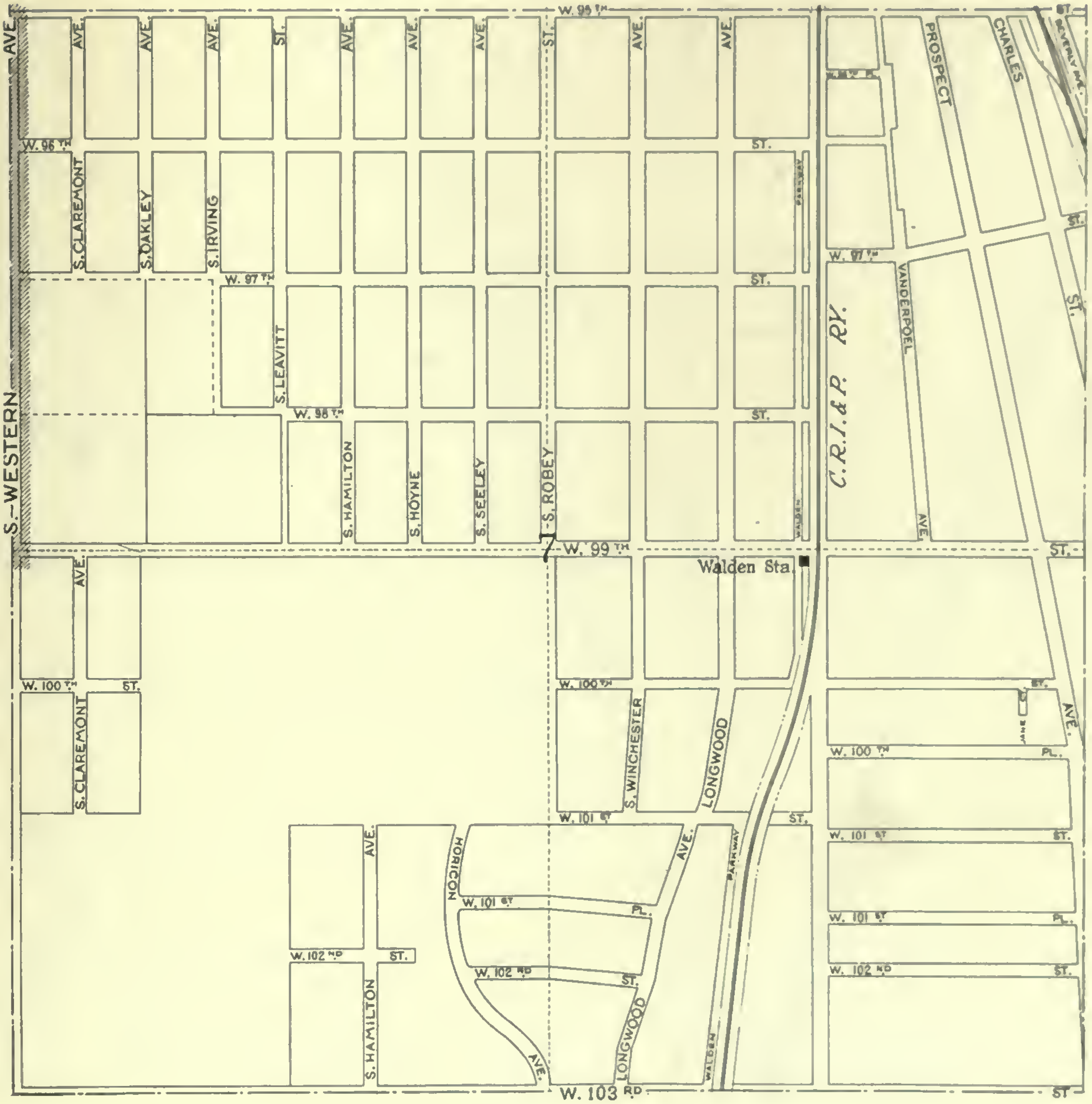

FIG. 236. SECTION MAP, INDEX NO. 142

Section 7 — Twp. 37 N. — R. 14 E. — 3 P. M. Scale: 1" = 800'

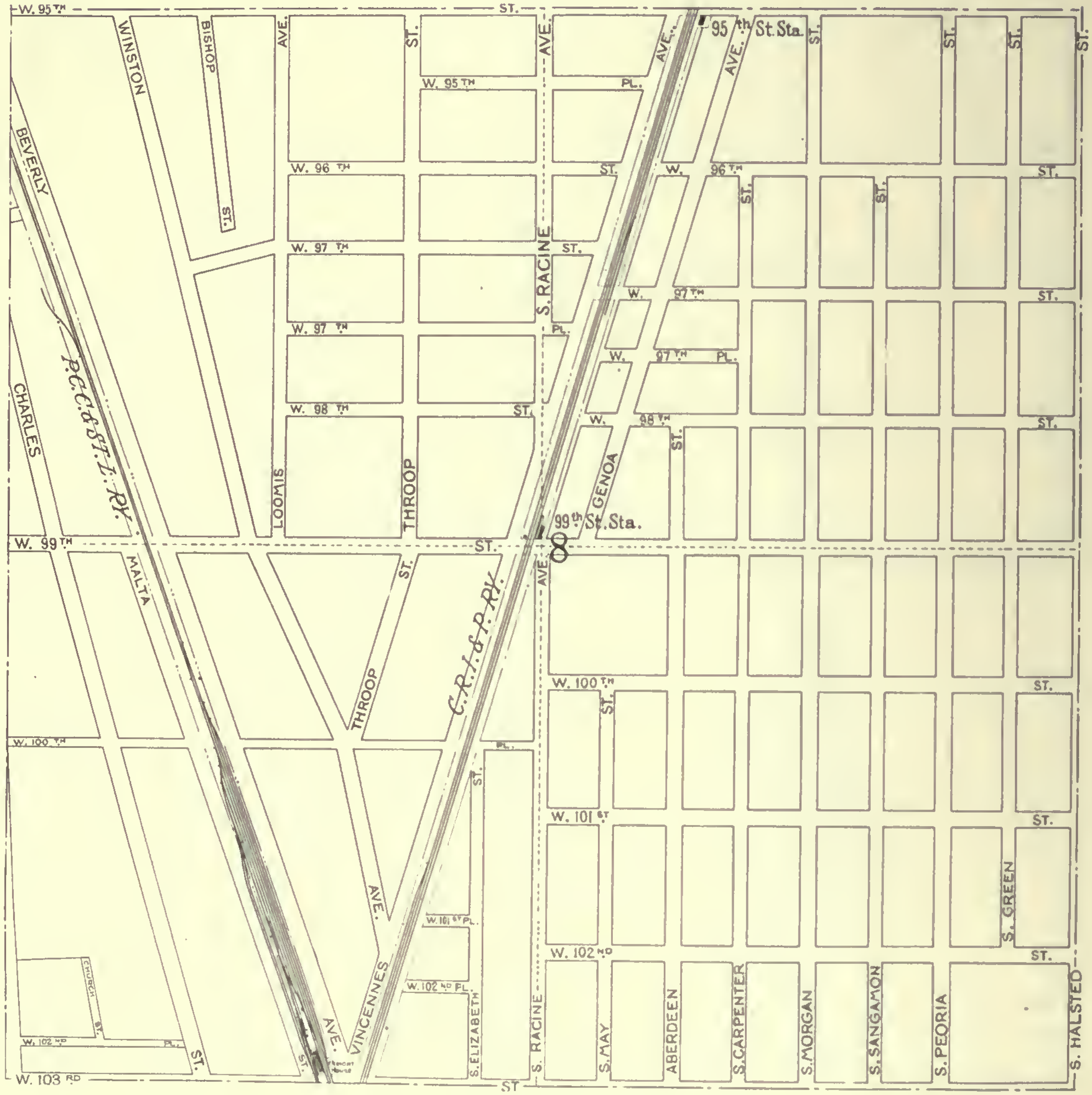

FIG. 237. SECTION MAP, INDEX NO 143

Section 8 — Twp. 37 N. — R 14 E. — 3 P. M. Scale: 1″ = 800′

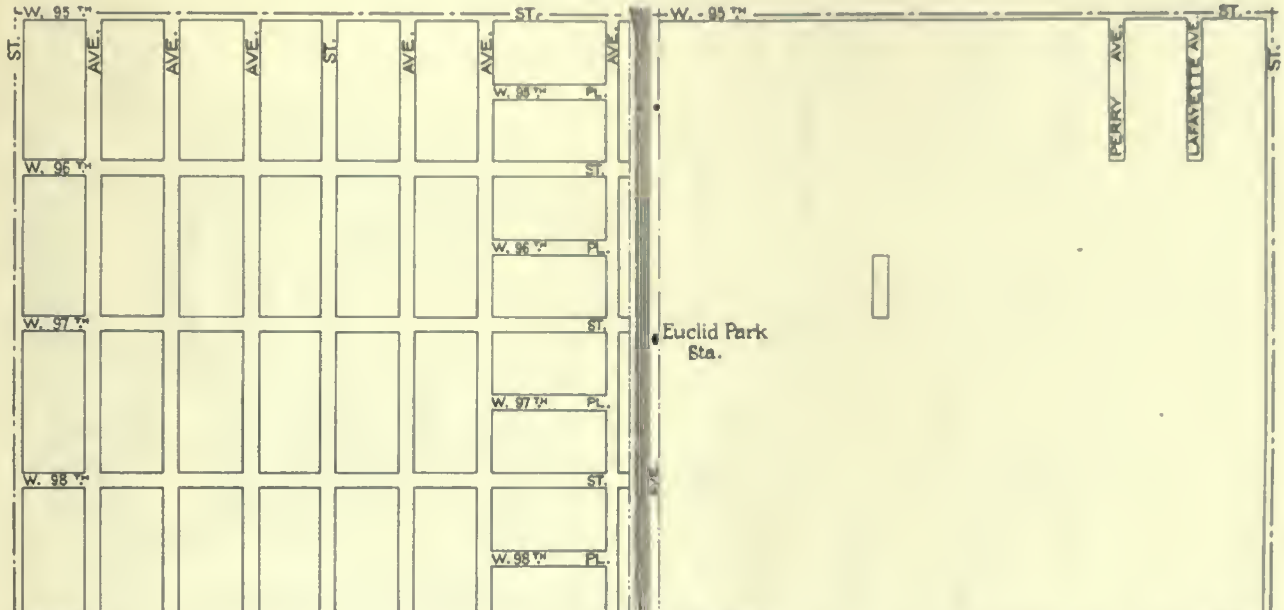

FIG. 238. SECTION MAP, INDEX NO. 144

Section 9—Twp. 37 N.—R. 14 E.—3 P. M. Scale: 1″ = 800′

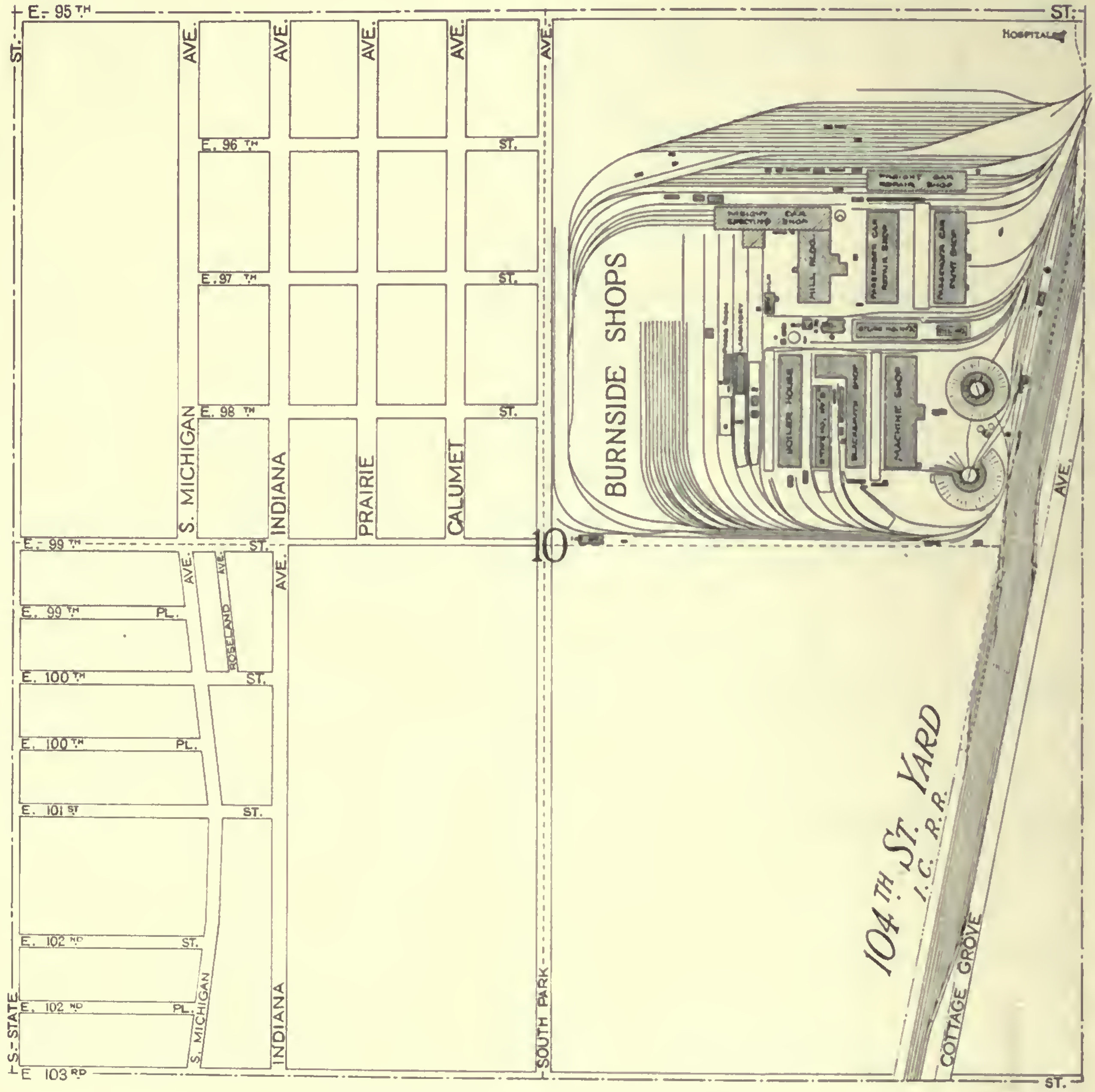

FIG. 239. SECTION MAP, INDEX NO. 145
Section 10 — Twp. 37 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

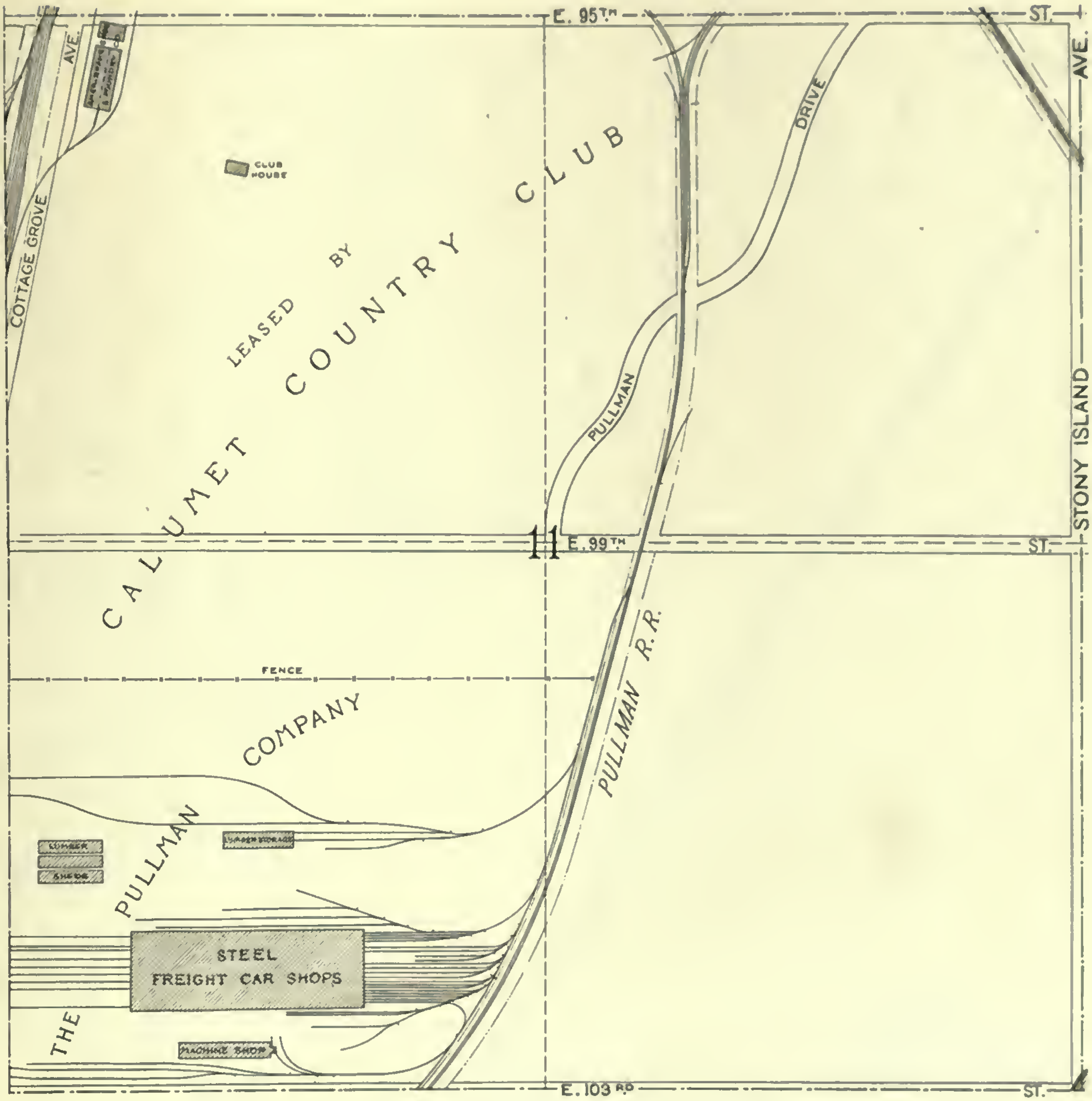

FIG. 240. SECTION MAP, INDEX NO. 146

Section 11 — Twp. 37 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

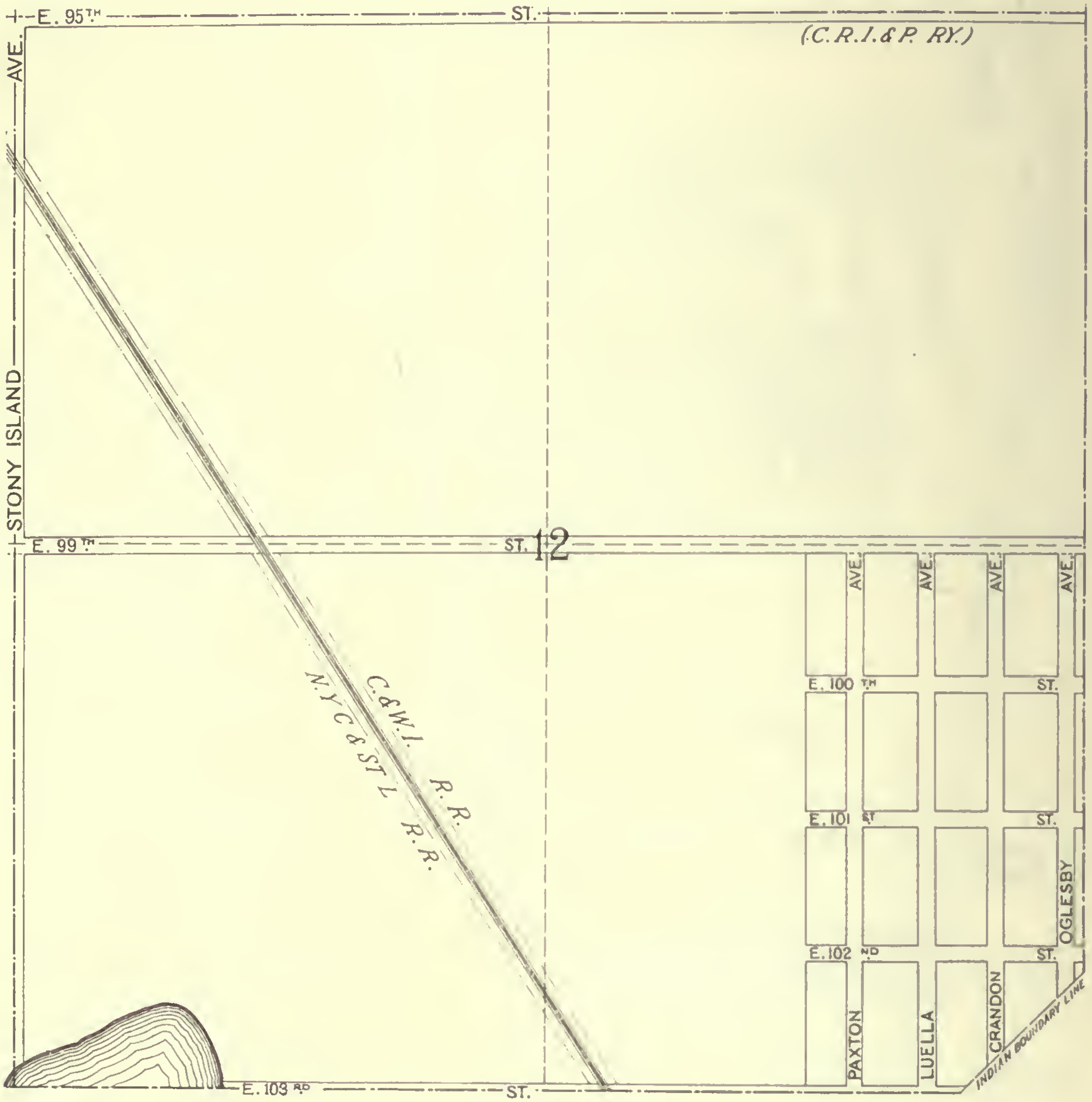

FIG. 241. SECTION MAP, INDEX NO. 147

Section 12 — Twp. 37 N. — R. 14 E. — 3 P. M. Scale: 1″ = 800′

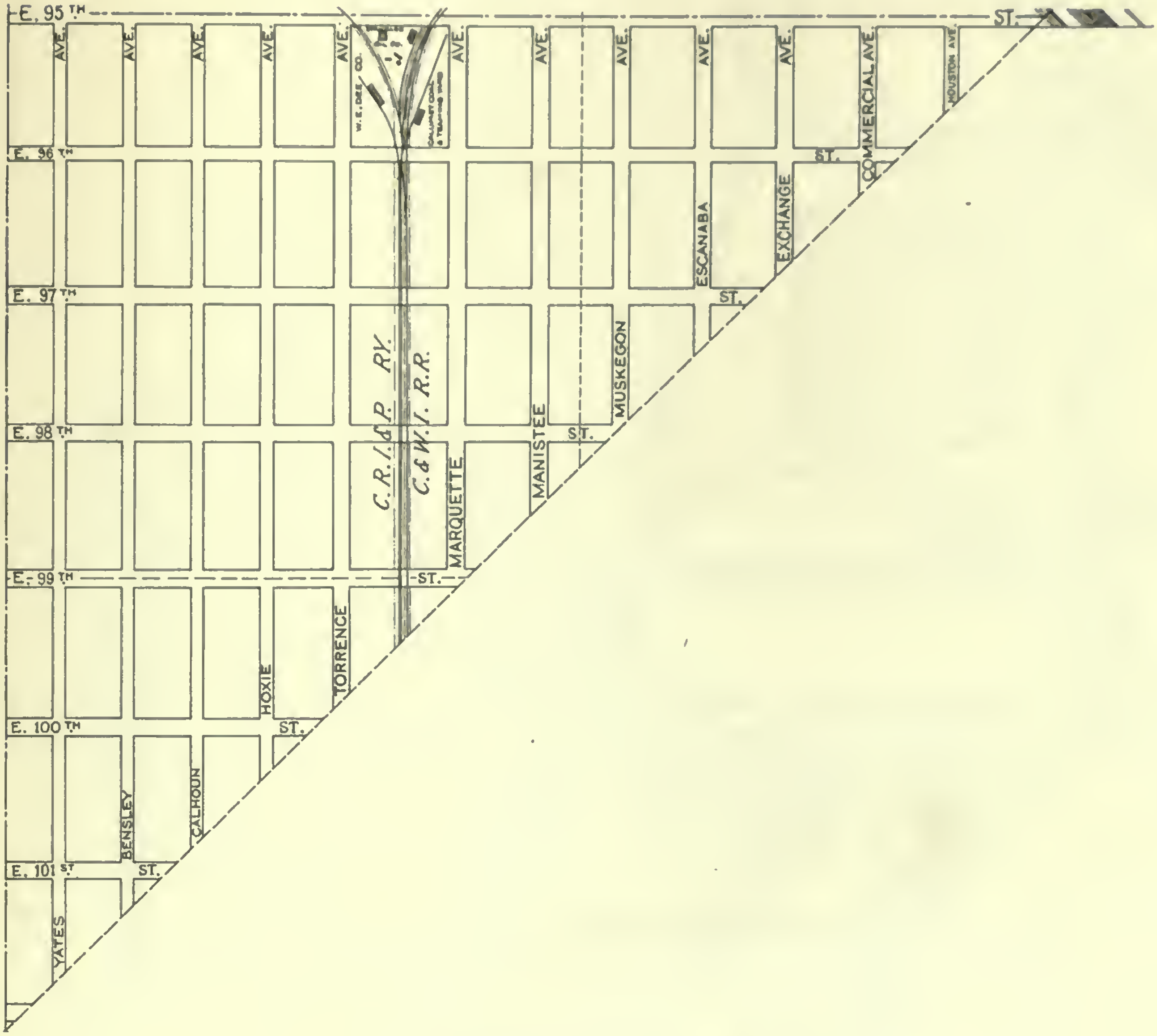

FIG. 242. SECTION MAP, INDEX NO. 148

Fractional Section 7 North of the Indian Boundary Line. Twp. 37 N. — R. 15 E. — 3 P. M. Scale: 1" = 800'

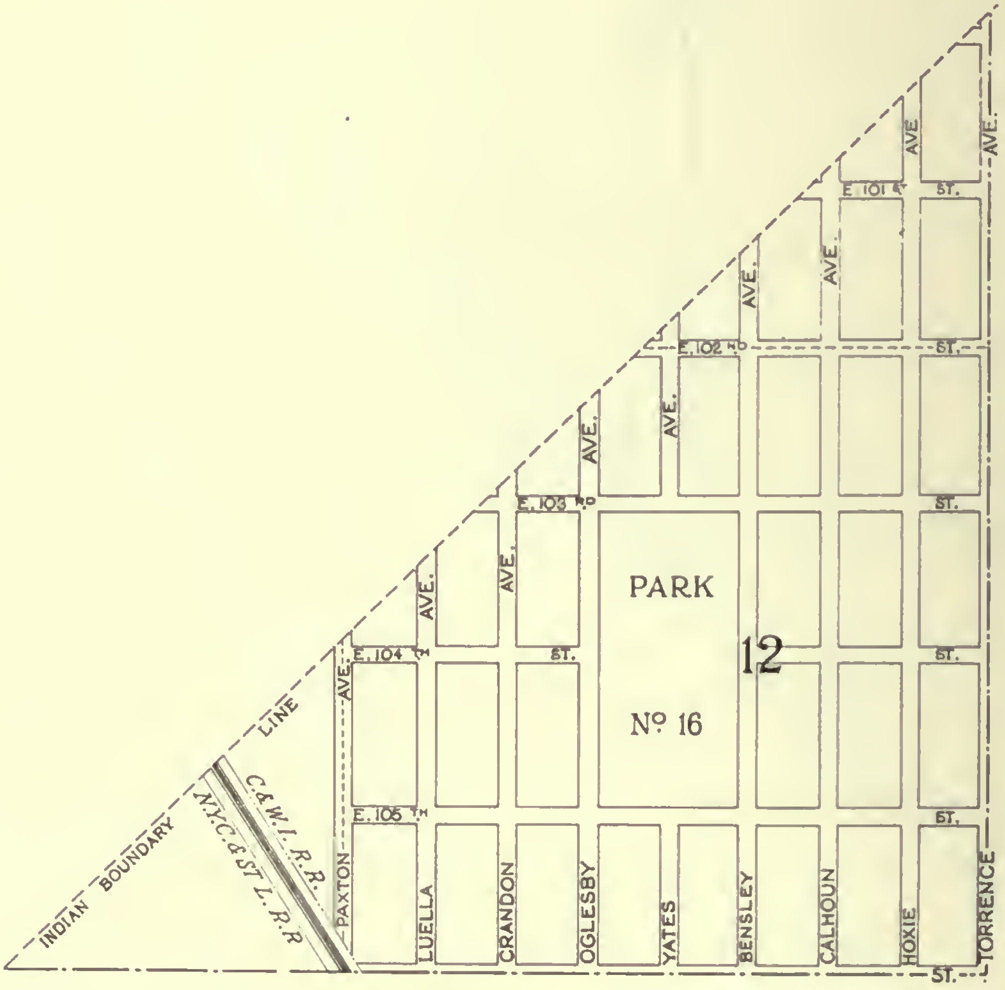

FIG. 243. SECTION MAP, INDEX NO. 149
Fractional Section 12 — Twp. 37 N. — R. 15 E. — 3 P. M. Scale: 1″ = 800′

FIG. 244. SECTION MAP, INDEX NO. 150

Fractional Sections 6 and 7—Twp. 37 N.—R. 15 E.—3 P. M. Scale: 1″=800′

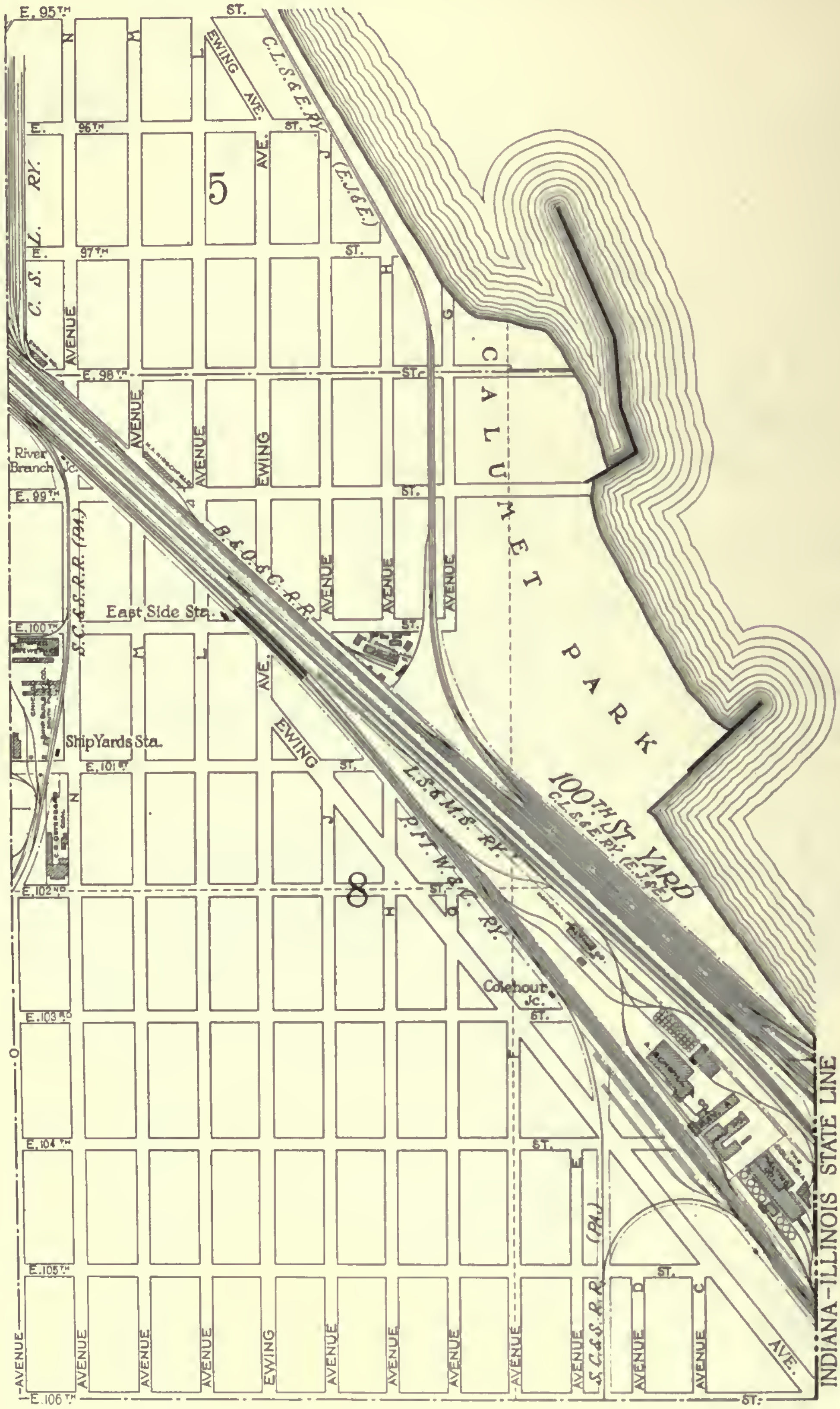

FIG. 245. SECTION MAP, INDEX NO. 151

Fractional Sections 5 and 8 — Twp. 37 N. — R. 15 E. — 3 P. M. Scale: 1″ = 800′

201.03 Density of Trackage: When the city was small and its future growth problematical, the railroads naturally placed their establishments as close as possible to the business district as it existed at that time. In time the city expanded and enveloped these establishments, thereby preventing their enlargement to meet the growing demands of the railroads. As a result, the railroads have been forced to make their extensions by establishing new facilities farther out at points where land was available. In some cases this process has been repeated two or three times, until many large yards and other establishments have been located in the outlying districts. Examples of these large outlying yards are the Proviso Yard of the Chicago & North Western Railway at Proviso, Ill., the Godfrey Yard of the Chicago, Milwaukee & St. Paul Railway at Mannheim, Ill., the Wildwood Yard of the Illinois Central Railroad near the southern city limits, and the Glenn Yard of the Chicago & Alton Railroad at Glenn, Ill. All of these yards are of comparatively recent construction and are being enlarged from time to time as additional facilities are required.

The progressive character of the growth of the railroads may be emphasized by comparing the extent of trackage in districts located at varying distances from the center of the city. If, with the Chicago City Hall as a center, a series of concentric circles are drawn with radii of one, two, three, four, five and six miles, respectively, it will be found that within the first circle, two miles in diameter, there are 78 miles of track devoted to yard purposes, or an average of 27 miles of track to each square mile of land within the circle. In the area between the first and second circles there are 141 miles of track devoted to yard purposes, or 23.5 miles of track per square mile of land; in that between the second and third circles there are 174 miles of such track, or 19.3 miles of track per square mile of land; in that between the third and fourth circles there are 111 miles of such track, or 9.1 miles of track per square mile of land; in that between the fourth and fifth circles there are 131 miles of such track, or 8.6 miles of track per square mile of land; and in that between the fifth and sixth circles there are 320 miles of such track, or 17.2 miles of track per square mile of land. That portion of the entire area circumscribed by the sixth circle, which lies within the city of Chicago, embraces 63.9 square miles, or 33.3 per cent of the total area of the city. Within this territory are located 955 miles of yard track, or 52.4 per cent of all the yard tracks of the city. Thus, within this particular portion of the city, representing a third of its area, are located more than one-half of all the yard tracks of Chicago.

A further idea of the extent of the railroad establishments in the Chicago District may be gained by studying the relation between the areas occupied by railroads and the entire area of the city. For purposes of comparison it may be assumed that any area on which railroad tracks are laid on 13-foot centers is entirely occupied; that the track density on such an area is 100 per cent. Upon this basis the trackage density of the area lying within six miles of the Chicago City Hall is 5.2 per cent, while that of the entire city is 3.6 per cent.

The territory lying between State and Canal streets and between Monroe and Sixteenth streets is occupied by four large passenger terminals, many freight houses and a number of yards and locomotive terminals. Similar conditions exist in the district along Kinzie Street from Ada Street to Lake Michigan. Here the improvements are old and part of the tracks are at grade.

A high trackage density also exists in the square mile between State and Halsted streets from 47th Street to 55th Street. This territory embraces the 51st Street Yard of the Chicago & Western Indiana Railroad, with 53 miles of track, and the Garfield Boulevard Yard of the Pittsburgh, Fort Wayne & Chicago Railway, which has more than 40 miles of track. These two yards present a high degree of economy of space, both being laid with track centers as close together as is practicable where tracks are used for various purposes. The district in the vicinity of 95th Street and Commercial Avenue also presents a very complicated situation from the standpoint of railroad trackage and its related facilities.

201.04 Railroad Companies Operating in the City of Chicago:* There are 23 steam railroads classed as trunk lines which maintain both freight and passenger service within the Area of Investigation, either wholly over their own tracks

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* Basis of 1912.

or partly over their own tracks and partly over the tracks of other companies. A list of these roads follows:

Trunk Lines

1. Atchison, Topeka & Santa Fe Ry.
2. Baltimore & Ohio R. R.
3. Chesapeake & Ohio Ry. of Indiana.
4. Chicago & Alton R. R.
5. Chicago & Eastern Illinois R. R.
6. Chicago & Erie R. R.
7. Chicago & North Western Ry.
8. Chicago, Burlington & Quincy R. R.
9. Chicago Great Western R. R.
10. Chicago, Indiana & Southern R. R.
11. Chicago, Indianapolis & Louisville Ry.
12. Chicago, Milwaukee & St. Paul Ry.
13. Chicago, Rock Island & Pacific Ry.
14. Grand Trunk Western Ry.
15. Illinois Central R. R.
16. Lake Shore & Michigan Southern Ry.
17. Michigan Central R. R.
18. Minneapolis, St. Paul & Sault Ste. Marie Ry.
19. New York, Chicago & St. Louis R. R.
20. Pere Marquette R. R.
21. Pittsburgh, Cincinnati, Chicago & St. Louis Ry.
22. Pittsburgh, Fort Wayne & Chicago Ry.
23. Wabash R. R.

In addition, the Cleveland, Cincinnati, Chicago & St. Louis Railway has an arrangement by which its trains are brought into Chicago over the tracks of the Illinois Central Railroad, the locomotives and locomotive crews of the latter company being used. The Pere Marquette Railroad operates its passenger trains with its own locomotives over the tracks of the Pittsburgh, Fort Wayne & Chicago Railway from Clarke Junction, Ind., to a point near 16th Street and Stewart Avenue, and thence over tracks of the Baltimore & Ohio Chicago Terminal Railroad to the Grand Central Station. Freight trains of the Pere Marquette Railroad enter the city over tracks of the Baltimore & Ohio Chicago Terminal Railroad from Clarke Junction, Ind. Certain other railroads regularly operate one or more cars into Chicago as a part of the trains of other companies.

There are ten steam railroads in the Chicago District which may be classed as switching or belt lines. These are as follows:

Switching and Belt Lines

1. Baltimore & Ohio Chicago Terminal R. R.
2. Chicago & Illinois Western R. R.
3. Chicago & Western Indiana R. R. and the Belt Railway of Chicago.
4. Chicago Junction Ry.
5. Chicago River & Indiana R. R.
6. Chicago Short Line Ry.
7. Chicago Union Transfer Ry.
8. Elgin, Joliet & Eastern Ry.
9. Illinois Northern Ry.
10. Indiana Harbor Belt R. R.

Each of these railroads owns main and side tracks within the Area of Investigation.

There are five steam railroads in the Chicago District which may be classed as industrial railroads, or small railroads serving industrial establishments, the trackage of which lies wholly within the Area of Investigation. These are as follows:

Industrial Railroads

1. Calumet, Hammond & Southeastern R. R.
2. Chicago & Calumet River R. R.
3. Chicago, West Pullman & Southern R. R.
4. Manufacturers' Junction Ry.
5. Pullman R. R.

Some of these operating companies embrace two or more proprietary companies, the charter names of the various lines being retained. Thus, the Illinois Central Railroad owns and operates the Blue Island Railroad, the Chicago & Illinois Southern Railroad, the Chicago, Madison & Northern Railroad, the South Chicago Railroad and the Riverside & Harlem Railroad, in addition to which it also owns the Kensington & Eastern Railroad and a fourth interest in the St. Charles Air Line.

Several of the railroads, such as the Indiana Harbor Belt Railroad, have trackage arrangements permitting them to operate locomotives and cars over a very considerable portion of the entire trackage within the city. Nearly all the railroads in the Chicago District have access to the Union Stock Yards, while a large number of industries are served by different railroads under operating agreements with the roads owning the trackage which provides access to such industries.

Agreements by which the traffic of one railroad may be routed over the tracks of another company commonly involve contract relations, a detailed discussion of which is beyond the scope of this report. While contract provisions vary in different cases, these agreements generally provide that the tenant shall pay to the owning road an interest charge upon an agreed valuation of the facilities used, and that the cost of operation shall be divided between the owner and tenant on a "user" or "wheelage" basis.

Frequently, tracks and other facilities are "jointly owned," that is, each railroad using the tracks or facilities owns a proportionate share thereof. Many instances of this kind exist in Chicago, probably the most conspicuous being that of the St. Charles Air Line, which is owned by the Illinois Central Railroad, the Michigan Central Railroad, the Chicago, Burlington & Quincy Railroad and the Chicago & North Western Railway, in equal parts, and which forms an important connecting link between these railroads. Other examples of joint ownership of main tracks include a line from the Union Station to a point near Western Avenue, which is jointly owned by the Chicago, Milwaukee & St. Paul Railway and the Pittsburgh, Cincinnati, Chicago & St. Louis Railway, and a line from the Union Station to a point near 22d Street, which is jointly owned by the Pittsburgh, Fort Wayne & Chicago Railway and the Chicago & Alton Railroad. Tracks which form a connection between different railroads are usually jointly owned.

One railroad may lease from another the right to operate certain properties, the lessor retaining certain rights regarding the operation of its own trains. Prominent examples of such agreements in Chicago occur in the case of the Belt Railway of Chicago, which leases certain tracks and track facilities from the Chicago & Western Indiana Railroad, and in that of the Illinois Northern Railway, which leases a portion of the trackage of the Atchison, Topeka & Santa Fe Railway.

201.05 Trackage: The mileage of all classes of steam railroad track within the Committee's Area of Investigation has been carefully determined from the maps supplied by the various railroad companies. To facilitate this determination a special form was prepared upon which a complete record for each route element was entered. A reproduction of this form with typical entries is presented as fig. 246.

The information required for "Form A" was tabulated by the Committee's staff. Due allowance was made for the shrinkage of blue prints or for other causes affecting the accuracy of the work. The totals thus secured were carefully checked against mileage data furnished independently by the railroad companies from their records and from other available sources. In the case of some large industries, independent figures were also secured, thus affording a more complete check upon the work of the Committee.

All track was listed according to the classifications shown by "Form A." For each classification, information was compiled concerning the character of the road-bed, alignment, frogs and switches. Under "Main Running Tracks" were included those known as "main tracks," that is, the principal tracks of the company kept open for the regular passage of through freight and passenger trains. Under "Other Running Tracks" were included certain tracks usually designated as "switching or industrial leads," that is, tracks kept open for the free movement of locomotives while switching for industries, or for making movements partaking of the nature of main line work. "Passenger Car Yards" include tracks commonly designated as "Coach Tracks" and other tracks used for care of passenger cars at places other than the train sheds of the passenger stations. Tracks located within the confines of passenger terminal stations were designated as "Passenger Terminal Tracks."

"Freight Switching Tracks" include practically all of the tracks in the large switching yards. "Freight Terminal Tracks" include tracks which are used for freight purposes in the immediate vicinity of freight houses. "Team Tracks" include those tracks set aside for the placing of cars, the traffic to and from which is handled by teams. "Industrial Tracks," or those serving particular industries, are divided into two classes:

1. Those owned by the railroad company.
2. Those owned by an industry but connected physically with the railroad under which they are listed.

It is customary, in the case of this class of tracks, for the railroad to retain title to that portion of an industrial track which is located upon its right-of-way, while the industry holds title to that portion which is not located upon railroad land. However, there are many exceptions to this general rule; industrial tracks have been constructed under such widely varying conditions that no general rule is applicable to particular cases. Statistical facts concerning the number of industries having track connections are elsewhere presented (section 103.05). The private ownership of any considerable amount of railroad trackage is confined to relatively few concerns.

"Roundhouse Tracks" include those serving the locomotive terminals as well as those within the building itself. "Shop Tracks" include all tracks serving repair shops. This applies not only to the tracks within the various buildings used for shop purposes, but also to the tracks outside of the structures and used in connection therewith.

Tracks which are used for various purposes have been classified according to their most extensive use. All narrow gage tracks have been omitted, as have also isolated sections of track, the location of which will not permit the continuous interchange of traffic. Included in such isolated tracks are wheel tracks, tram tracks in repair yards, tracks carrying transfer tables, or other tracks on which standard gage engines or cars are not operated. Abandoned track has not been included. All crossovers are accounted for, both in number and in length. The data herein presented are complete to the end of the Committee's statistical year, 1912.

In many cases personal inspection trips were made to test the accuracy of maps submitted by the railroads. The net result of this work is believed to be an accurate statement of the steam railroad trackage of Chicago and its vicinity.

A retabulation of the data presented in "Form A" (fig. 246) is set forth by tables CXXXIII to CXLVII, inclusive.

The mileage given in the tables presented does not agree in all cases with the figures given in various printed documents, such as the tax list and the reports of the Interstate Commerce Commission, for the reason that in these publications privately owned industrial tracks have not been included, and in some cases accurate information relative to abandoned track and crossovers has evidently not been available to persons compiling them. Complete agreement is further precluded by the fact that the tables herein presented are corrected for new track lay-outs, data concerning which are not presented in published statistics of other bodies.

201.06 Grade Crossings: Each of the railroad companies in the Chicago District was requested to supply information concerning all avenues of traffic which crossed their tracks at grade throughout the Area of Investigation. The nature and extent of the data thus requested are set forth in "Form E," "Statement of Grade Crossings," which is reproduced as fig. 247.

A summarized statement of facts of interest concerning crossings at grade is presented by tables CXLVIII to CLIII, inclusive, and by the map, fig. 248.

A correct interpretation of the information given in the tables presented requires that note be taken of the fact that the total number of crossings is a summary of the number for each railroad. For example, if a street crosses three different railroads lying side by side, the number of street crossings is given as three since each of the three railroads reported it.

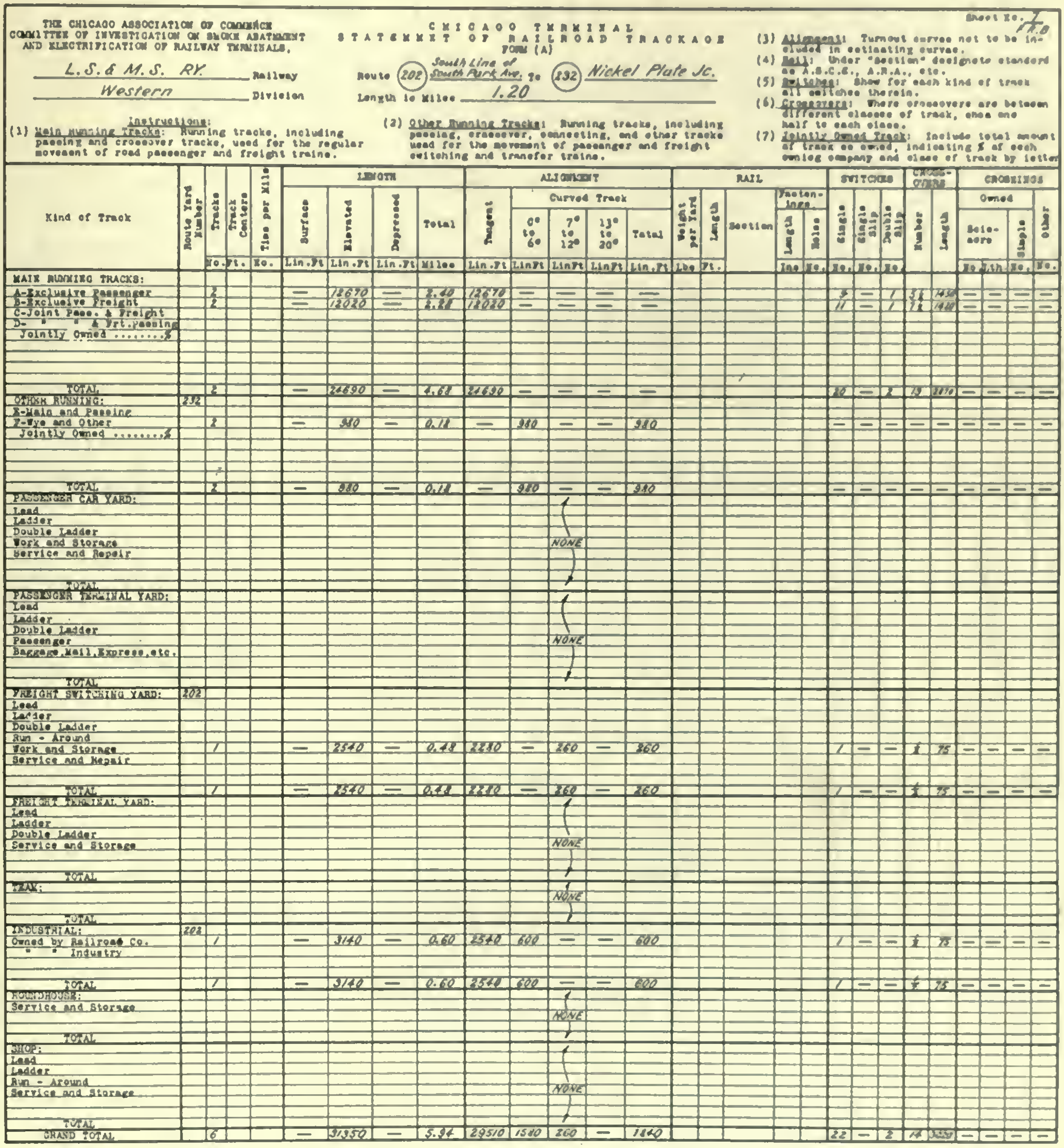
Of all crossings of steam railroads by steam railroads at grade, more than 82 per cent are equipped with some form of automatic or mechanical protection, the remainder being subject to protection by hand signals. Of the grade crossings of steam railroads by streets and highways, 72 per cent are protected in some manner. At least 75 per cent of all grade crossings within the Area of Investigation are equipped with some form of protection.

Views of various grade crossings throughout the Area of Investigation are presented as figs. 249 to 262, inclusive.

201.07 Bridges: All steam railroads in the Chicago District were requested to furnish complete information concerning all track structures on their lines, within the Area of Investigation. For this purpose each railroad was supplied with copies of "Form D," "Statement of Bridges, Culverts and Overhead Crossings," a reproduction of which is presented as fig. 263.

A summary of all railroad under crossings is presented in table CLIV and of all railroad overhead crossings in table CLV.

It was obvious that certain structures would be reported twice, as for instance, in cases where



THE CHICAGO ASSOCIATION OF COMMERCE
COMMITTEE OF INVESTIGATION ON SMOKE ABATEMENT
AND ELECTRIFICATION OF RAILWAY TERMINALS.

CHICAGO TERMINAL
STATEMENT OF RAILROAD TRACKAGE
FORM (A)

Sheet No. 7
F.R.B

L.S. & M.S. RY. Railway
Western Division

Route (202) South Line of South Park Ave. to (232) Nickel Plate Jc.
Length in Miles 1.20

Instructions:

(1) Main Running Tracks: Running tracks, including passing and crossover tracks, used for the regular movement of road passenger and freight trains.

(2) Other Running Tracks: Running tracks, including passing, crossover, connecting, and other tracks used for the movement of passenger and freight switching and transfer trains.

(3) Alignment: Turnout curves not to be included in estimating curves.

(4) Rail: Under "Section" designate standard as A.S.C.E., A.R.A., etc.

(5) Switches: Show for each kind of track all switches therein.

(6) Crossovers: Where crossovers are between different classes of track, show one half to each class.

(7) Jointly Owned Track: Include total amount of track so owned, indicating % of each owning company and class of track by letter

Kind of Track	Route Yard Number	Tracks	Track Centers	Ties per Mile	LENGTH				ALIGNMENT					RAIL					SWITCHES			CROSS-OVERS		CROSSINGS			
					Surface	Elevated	Depressed	Total	Tangent	Curved Track				Weight per Yard	Length	Section	Fastenings		Single	Single Slip	Double Slip	Number	Length	Owned			Other
										0° to 6°	7° to 12°	13° to 20°	Total				Length	Holes						Scissors		Simple	
		No.	Ft.	No.	Lin.Ft	Lin.Ft	Lin.Ft	Miles	Lin.Ft	LinFt	LinFt	LinFt	Lin.Ft	Lbs	Ft.		Ins	No.	No.	No.	No.			No	Lth.	No.	No.
MAIN RUNNING TRACKS:																											
A-Exclusive Passenger		2			—	12670	—	2.40	12670	—	—	—	—						9	—	1	5½	1450	—	—	—	—
B-Exclusive Freight		2			—	12020	—	2.28	12020	—	—	—	—						11	—	1	7½	1420	—	—	—	—
C-Joint Pass. & Freight																											
D- " " & Frt.Passing																											
Jointly Owned ....%																											
TOTAL		2			—	24690	—	4.68	24690	—	—	—	—						20	—	2	13	2870	—	—	—	—
OTHER RUNNING:	232																										
E-Main and Passing																											
F-Wye and Other		2			—	980	—	0.18	—	980	—	—	980						—	—	—	—	—	—	—	—	—
Jointly Owned ....%																											
TOTAL		2			—	980	—	0.18	—	980	—	—	980						—	—	—	—	—	—	—	—	—
PASSENGER CAR YARD:																											
Lead																											
Ladder																											
Double Ladder																											
Work and Storage											NONE																
Service and Repair																											
TOTAL																											
PASSENGER TERMINAL YARD:																											
Lead																											
Ladder																											
Double Ladder																											
Passenger											NONE																
Baggage,Mail,Express,etc.																											
TOTAL																											
FREIGHT SWITCHING YARD:	202																										
Lead																											
Ladder																											
Double Ladder																											
Run - Around																											
Work and Storage		1			—	2540	—	0.48	2280	—	260	—	260						1	—	—	½	75	—	—	—	—
Service and Repair																											
TOTAL		1			—	2540	—	0.48	2280	—	260	—	260						1	—	—	½	75	—	—	—	—
FREIGHT TERMINAL YARD:																											
Lead																											
Ladder																											
Double Ladder																											
Service and Storage											NONE																
TOTAL																											
TEAM:																											
											NONE																
TOTAL																											
INDUSTRIAL:	202																										
Owned by Railroad Co.		1			—	3140	—	0.60	2540	600	—	—	600						1	—	—	½	75	—	—	—	—
" " Industry																											
TOTAL		1			—	3140	—	0.60	2540	600	—	—	600						1	—	—	½	75	—	—	—	—
ROUNDHOUSE:																											
Service and Storage																											
											NONE																
TOTAL																											
SHOP:																											
Lead																											
Ladder																											
Run - Around																											
Service and Storage											NONE																
TOTAL																											
GRAND TOTAL		6			—	31350	—	5.94	29510	1580	260	—	1840						22	—	2	14	[illegible]	—	—	—	—

FIG. 246. "FORM A" STATEMENT OF THE TRACKAGE OF A RAILROAD ROUTE ELEMENT, CHICAGO TERMINALS

TABLE CXXXIII. MILEAGE OF ALL CLASSES OF STEAM RAILROAD TRACK. ZONES A AND B
(Basis of 1912)

Kind of Track	Tracks	Length				Alignment					Switches			Crossovers		Crossings			
							Curved Track									Owned			
																Scissors		Simple	Other
		Surface	Elevated	Depressed	Total*	Tangent	0° to 6°	7° to 12°	13° and over	Total	Single	Single Slip	Double Slip	Total	Length				
	No.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Miles	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	No.	No.	No.	No.	Lin. Ft.	No.	Lth.	No.	No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Main Running:																			
Exclusive passenger		629,372	691,610	13,370	252.72	1,114,110	206,062	12,750	1,430	220,242	433	5	74	191	38,769	3	594	122	59
Exclusive freight		1,897,050	742,160	4,480	500.70	2,195,003	376,762	68,315	3,610	448,687	1,884	2	90	502	90,415	11	1,974	290	239
Joint passenger and freight		3,183,633	875,492		768.77	3,579,718	418,499	58,036	2,872	479,407	1,765	2	72	494	92,749			410	431
Joint pass. and freight passing		53,749	12,455		12.54	58,961	4,483	2,660	100	7,243	58	0	1	11	2,010			7	
Totals		5,763,804	2,321,717	17,850	1,534.73	6,947,792	1,005,806	141,761	8,012	1,155,579	4,140	9	237	1,198	223,943	14	2,568	829	729
Other Running:																			
Main and passing	102	332,564	51,275		72.70	303,720	37,160	31,058	11,901	80,119	409	0	8	59	11,068			8	7
Wye and other	365	335,531	146,374		91.27	286,722	74,328	83,662	37,193	195,183	353	0	10	72	13,021	4	640	65	4
Totals	467	668,095	197,649		163.97	590,442	111,488	114,720	49,094	275,302	762	0	18	131	24,089	4	640	73	11
Passenger Car Yard:																			
Lead	10	6,363	11,883		3.45	15,828	520	1,653	245	2,418	8	0	1						
Ladder	34	22,496	12,742		6.68	23,555	3,970	6,268	1,445	11,683	312	0	2	5	925			1	
Double ladder †	(3)	(1,402)	(400)		(0.34)														
Work and storage	342	195,847	124,123	9,370	62.37	258,609	3,050	48,509	19,172	70,731	187	0	5	21	3,862			4	
Service and repair	64	7.300	38.305		8.64	32,727	4,120	6,740	2,018	12,878	24	0	0	2	230				
Totals	450	232.006	187,053	9,370	81.14	330,719	11,660	63,170	22,880	97,710	531	0	8	28	5,017			5	
Passenger Terminal Yard:																			
Lead	2	7,580			1.44	5,980	1,600			1,600	7	0	0	2	460				
Ladder	12	4,445	1,580	1,140	1.36	4,450	1,400	915	400	2,715	43	0	14	1	280			1	
Double ladder †																			
Passenger	72	30,840	35,288	12,730	14.93	59,523	1,700	16,125	1,510	19,335	86	2	26	30	5,420	4	1,270		
Baggage, mail, express, etc.	52	23,302	6,050	1,000	5.75	21,275	610	7,567	900	9,077	25	0	1	4	690				
Totals	138	66,167	42,918	14,870	23.48	91,228	5,310	24,607	2,810	32,727	161	2	41	37	6,850	4	1,270	1	
Freight Switching Yard:																			
Lead	237	338,284	63,335		76.06	321,784	44,210	20,625	15,000	79,835	409	0	19	68	12,700	2	540	6	2
Ladder	517	351,798	97,194		85.04	349,152	16,202	42,318	41,320	99,840	4,541	0	82	60	10,415			3	
Double ladder †	(29)	(15,235)	(4,330)		(3.71)														
Run-around	101	263,923	37,300		57.05	237,783	23,885	32,335	7,220	63,440	242	0	3	62	10,630				
Work and storage	3,973	5,928,845	1,369,336		1,382.23	5,970,321	281,253	503,393	543,214	1,327,860	2,189	0	47	289	51,464			23	4
Service and repair	400	292,431	78,729		70.30	292,206	13,535	38,934	26,485	78,954	311	0	1	25	4,120			1	
Totals	5,228	7,175,281	1,645,894		1,670.68	7,171,246	379,085	637,605	633,239	1,649,929	7.692	0	152	504	89,329	2	540	33	6
Freight Terminal Yard:																			
Lead	13	6,181		11,550	3.36	13,651	650	3,010	420	4,080	32	2	21	7	1,260			10	
Ladder	22	10,021		7,110	3.25	12,477	2.230	1,774	650	4,654	126	0	1	4	800			2	
Double ladder †																			
Service and storage	436	275.384		125,062	75.84	283,901	35,050	54,833	26,662	116,545	377	0	8	44	8,203	1	230		
Totals	471	291,586		143,722	82.45	310,029	37,930	59,617	27,732	125,279	535	2	30	55	10,263	1	230	12	
Team	515	334,587	44,758	13,330	74.37	289,390	22,314	56,233	24,738	103,285	334	0	7	10	1,960			2	
Totals	515	334,587	44,758	13,330	74.37	289,390	22,314	56,233	24,738	103,285	334	0	7	10	1,960			2	
Industrial:																			
Owned by railroad company	2,497	1,918,382	114,331	4,240	385.79	1,395,384	73,581	345,112	222,876	641,569	2,181	0	31	133	20,565	1	160	113	18
Owned by industry	1,514	1,131,080	34,298		220.71	792,025	40,940	159,717	172,696	373,353	1,013	0	4	31	5,225	1	160	30	22
Totals	4,011	3,049,462	148,629	4,240	606.50	2,187,409	114,521	504,829	395,572	1,014,922	3,194	0	35	164	25,790	2	320	143	40
Roundhouse:																			
Service and storage	1,302	455,220	23,545		90.67	358,994	24,272	59,650	35,849	119,771	503	0	6	35	6,335	1	650	4	
Totals	1,302	455,220	23,545		90.67	358,994	24,272	59,650	35,849	119,771	503	0	6	35	6,335	1	650	4	
Shop:																			
Lead	11	29,027			5.50	17,815	330	10,752	130	11,212	19								
Ladder	16	14,893	1,220		3.05	11,350		3,813	950	4,763	140								
Run-around	5	11,501			2.18	7,771	700	3,030		3,730	8			1	190				
Service and storage	368	460,658	4,530		88.10	394,366	13,589	39,703	17,530	70,822	241	0	0	11	2,092			2	
Totals	400	516,079	5,750		98.83	431,302	14,619	57,298	18,610	90,527	408	0	0	12	2,282			2	
Grand Totals	12,982	18,552,287	4,617,913	203,382	4,426.82	18,708,551	1,727,005	1,719,490	1,218,536	4,665,031	18,260	13	534	2,174	395,858	28	6,218	1,104	786

* Exclusive of crossovers. † Double ladder tracks counted once under single ladder tracks, hence not included in totals.

TABLE CXXXIV. MILEAGE OF ALL CLASSES OF STEAM RAILROAD TRACK. ZONE A. CITY OF CHICAGO*
(Basis of 1912)

Kind of Track	Tracks	Length				Alignment					Switches			Crossovers		Crossings			
		Surface	Elevated	De-pressed	Total †	Tangent	Curved Track				Single	Single Slip	Double Slip	Total	Length	Owned			Other
							0° to 6°	7° to 12°	13° and over	Total						Scissors		Sim-ple	
	No.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Miles	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	No.	No.	No.	No.	Lin. Ft.	No.	Lth.	No.	No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Main Running:																			
Exclusive passenger		315,082	667.248	13,370	188.58	820.364	161,156	12.750	1.430	175,336	389	5	74	173	34,374	3	594	88	57
Exclusive freight		703,744	727.610	4.480	271.94	1,201.218	175,334	56,342	2.940	234,616	1,263	2	66	342	60.620	11	1,974	219	125
Joint passenger and freight		1.395,887	754.502		407.27	1.833.637	266,894	46,986	2.872	316.752	1,175		60	336	61.732			290	300
Joint pass. and freight passing		16,000	12.455		5.39	26,125	1,500	730	100	2.330	41		1	8	1,450				
Totals		2,430,713	2,161.815	17,850	873.18	3.881,344	604,884	116.808	7,342	729,034	2.868	7	201	859	158,176	14	2,568	597	482
Other Running:																			
Main and passing	65	166,561	46.650		40.38	158,612	21.460	26.008	7,131	54,599	339		5	44	7.983			8	4
Wye and other	204	118,456	146,374		50.16	156,794	44.273	49.558	14,205	108.036	241		10	55	9,756	4	640	56	2
Totals	269	285,017	193,024		90.54	315,406	65.733	75.566	21.336	162.635	580		15	99	17,739	4	640	64	6
Passenger Car Yard:																			
Lead	10	6.363	11,883		3.45	15.828	520	1,653	245	2.418	8		1						
Ladder	32	21.300	12,742		6.45	22.555	3,970	6,072	1,445	11.487	304		2	5	925			1	
Double ladder ‡	(3)	(1,402)	(400)		(0.34)														
Work and storage	324	179.946	124.123	9,370	59.36	245.109	3.050	46,108	19.172	68,330	169		5	21	3,862			4	
Service and repair	64	7,300	38.305		8.64	32.727	4.120	6 740	2.018	12.878	24			2	230				
Totals	430	214,909	187.053	9.370	77.90	316.219	11.660	60.573	22.880	95.113	505		8	28	5,017			5	
Passenger Terminal Yard:																			
Lead	2	7,580			1.44	5.980	1.600			1,600	7			2	460				
Ladder	12	4.445	1.580	1,140	1.36	4.450	1.400	915	400	2,715	43		14	1	280			1	
Double ladder ‡																			
Passenger	72	30.840	35.288	12.730	14.93	59.523	1.700	16.125	1.510	19,335	86	2	26	30	5,420	4	1,270		
Baggage. mail. express, etc.	52	23.302	6.050	1,000	5.75	21.275	610	7.567	900	9,077	25		1	4	690				
Totals	138	66.167	42.918	14.870	23.48	91,228	5.310	24.607	2,810	32,727	161	2	41	37	6,850	4	1,270	1	
Freight Switching Yard:																			
Lead	123	132.988	63.335		37.18	156.653	17,090	15.215	7,365	39,670	199		8	33	5,835	1	360	4	2
Ladder	299	154.443	97.194		47.66	194,587	10.632	33.658	12.760	57,050	2,684		34	30	5,295			3	
Double ladder ‡	(17)	(5.920)	(4.330)		(1.94)														
Run-around	52	120.727	37.300		29.93	120.692	12.680	20.625	4.030	37,335	129			29	5,180				
Work and storage	2.570	2,859,595	1.356,186		798.44	3.366.374	201.298	360.755	287.354	849,407	1,631		22	182	33,105			20	
Service and repair	303	177,601	78.729		48.55	206.716	8.585	25.734	15.295	49.614	248		1	19	3,280				
Totals	3,347	3.445,354	1.632.744		961.76	4,045.022	250.285	455.987	326,804	1,033,076	4.891		65	293	52,695	1	360	27	2
Freight Terminal Yard:																			
Lead	13	6.181		11,550	3.36	13.651	650	3.010	420	4.080	32	2	21	7	1,260			10	
Ladder	22	10.021		7,110	3.25	12.477	2.230	1,774	650	4,654	126		1	4	800			2	
Double ladder ‡																			
Service and storage	436	275.384		125.062	75.84	283.901	35.050	54,833	26,662	116.545	377		8	44	8,203	1	230		
Totals	471	291,586		143.722	82.45	310.029	37.930	59.617	27.732	125,279	535	2	30	55	10.263	1	230	12	
Team	449	274.417	44.758	13,330	62.97	245.410	20,104	47.653	19,338	87.095	313		7	9	1,780			1	
Totals	449	274,417	44.758	13,330	62.97	245.410	20.104	47,653	19,338	87.095	313		7	9	1,780			1	
Industrial:																			
Owned by railroad company	2.036	1.373.269	113.581	4.240	282.40	1.019.982	58,607	258,261	154,240	471.108	1,805		17	95	14,410			85	15
Owned by industry	1.214	821.271	33,998		161.98	582.005	29.005	111.419	132,840	273,264	682		2	23	3,720	1	160	29	21
Totals	3.250	2.194.540	147.579	4.240	444.38	1,601,987	87,612	369.680	287,080	744.372	2,487		19	118	18,130	1	160	114	36
Roundhouse:																			
Service and storage	1.043	337.597	23,545		68.40	270,603	20,272	47,998	22,269	90.539	360		1	21	3,915	1	650	4	
Totals	1.043	337.597	23.545		68.40	270.603	20,272	47,998	22.269	90.539	360		1	21	3,915	1	650	4	
Shop:																			
Lead	8	26.242			4.97	15,445	330	10,467		10,797	14								
Ladder	12	10,180	1,220		2.16	7.700		3.400	300	3.700	81								
Run-around	5	11.501			2.18	7.771	700	3.030		3.730	8			1	190				
Service and storage	290	379.296	4.530		72.69	328,286	13.589	32,561	9.390	55,540	206			8	1,570			2	
Totals	315	427.219	5,750		82.00	359.202	14.619	49,458	9.690	73,767	309			9	1,760			2	
Grand Totals	9,712	9,967,519	4.439.186	203,382	2,767.06	11.436.450	1,118,409	1,307.947	747,281	3.173.637	13,009	11	387	1.528	276.325	26	5,878	827	526

* Does not include Morgan Park. † Exclusive of crossovers. ‡ Double ladder tracks counted once under single ladder tracks, hence not included in totals.

TABLE CXXXV. MILEAGE OF ALL CLASSES OF STEAM RAILROAD TRACK. ZONE B IN ILLINOIS AND INDIANA
(Basis of 1912)

Kind of Track	Tracks	Length			Alignment					Switches			Crossovers		Crossings			
						Curved Track									Owned			
		Surface	Elevated	Total *	Tangent	0° to 6°	7° to 12°	13° and over	Total	Single	Single Slip	Double Slip	Total	Length	Scissors		Simple	Other
	No.	Lin. Ft.	Lin. Ft.	Miles	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	No.	No.	No.	No.	Lin. Ft.	No.	Lth.	No.	No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Main Running:																		
Exclusive passenger		314.290	24,362	64.14	293.746	44,906			44.906	44			18	4,395			34	2
Exclusive freight		1,193.306	14,550	228.76	993,785	201,428	11.973	670	214.071	621		24	160	29,795			71	114
Joint passenger and freight		1,787.746	120,990	361.50	1.746,081	151,605	11.050		162,655	590	2	12	158	31,017			120	131
Joint passenger and freight passing		37.749		7.15	32,836	2,983	1,930		4,913	17			3	560			7	
Totals		3,333,091	159,902	661.55	3,066.448	400,922	24.953	670	426,545	1.272	2	36	339	65,767			232	247
Other Running:																		
Main and passing	37	166,003	4,625	32.32	145.108	15,700	5.050	4.770	25.520	70		3	15	3.085				3
Wye and other	161	217,075		41.11	129.928	30.055	34.104	22.988	87,147	112			17	3,265			9	2
Totals	198	383,078	4,625	73.43	275,036	45.755	39.154	27.758	112.667	182		3	32	6.350			9	5
Passenger Car Yard:																		
Lead																		
Ladder	2	1,196		0.23	1,000		196		196	8								
Double ladder †																		
Work and storage	18	15.901		3.01	13,500		2.401		2.401	18								
Service and repair																		
Totals	20	17.097		3.24	14.500		2.597		2,597	26								
Passenger Terminal Yard:	None																	
Lead																		
Ladder																		
Double ladder †																		
Passenger																		
Baggage, mail, express, etc.																		
Totals																		
Freight Switching Yard:																		
Lead	114	205,296		38.88	165,131	27.120	5,410	7,635	40.165	210		11	35	6,865	1	180	2	
Ladder	218	197,355		37.38	154,565	5,570	8,660	28.560	42,790	1,857		48	30	5,120				
Double ladder †	(12)	(9,315)		(1.77)														
Run-around	49	143,196		27.12	117,091	11.205	11.710	3,190	26.105	113		3	33	5,450				
Work and storage	1,403	3.069,250	13.150	583.79	2,603,947	79.955	142.638	255.860	478.453	558		25	107	18,359			3	4
Service and repair	97	114,830		21.75	85.490	4,950	13,200	11.190	29.340	63			6	840			1	
Totals	1,881	3.729.927	13.150	708.92	3,126,224	128,800	181,618	306.435	616.853	2.801		87	211	36.634	1	180	6	4
Freight Terminal Yard:	None																	
Lead																		
Ladder																		
Double ladder †																		
Service and storage																		
Totals																		
Team	66	60,170		11.40	43,980	2,210	8.580	5,400	16,190	21			1	180			1	
Totals	66	60.170		11.40	43,980	2,210	8,580	5.400	16,190	21			1	180			1	
Industrial:																		
Owned by railroad company	461	545,113	750	103.39	375,402	14,974	86,851	68.636	170,461	376		14	38	6.155	1	160	28	3
Owned by industry	300	309,809	300	58.73	210,020	11,935	48,298	39.856	100,089	331		2	8	1,505			1	1
Totals	761	854,922	1,050	162.12	585,422	26,909	135,149	108.492	270.550	707		16	46	7.660	1	160	29	4
Roundhouse:																		
Service and storage	259	117,623		22.27	88,391	4,000	11.652	13,580	29,232	143		5	14	2.420				
Totals	259	117,623		22.27	88,391	4.000	11.652	13,580	29,232	143		5	14	2,420				
Shop:																		
Lead	3	2,785		0.53	2,370		285	130	415	5								
Ladder	4	4.713		0.89	3.650		413	650	1,063	59								
Run-around																		
Service and storage	78	81,362		15.41	66.080		7.142	8,140	15.282	35			3	522				
Totals	85	88.860		16.83	72,100		7,840	8,920	16,760	99			3	522				
Grand Totals	3,270	8.584,768	178.727	1.659.76	7.272.101	608,596	411,543	471,255	1.491,394	5,251	2	147	646	119,533	2	340	277	260

* Exclusive of crossovers. † Double ladder tracks counted once under single ladder tracks, hence not included in totals.

TABLE CXXXVI. MILEAGE OF ALL CLASSES OF STEAM RAILROAD TRACK. ZONE B IN ILLINOIS

(Basis of 1912)

Kind of Track	Tracks	Length			Alignment					Switches		Crossovers		Crossings	
						Curved Track									
		Surface	Elevated	Total *	Tangent	0° to 6°	7° to 12°	13° and over	Total	Single	Double Slip	Total	Length	Owned Simple	Other
	No.	Lin. Ft.	Lin. Ft.	Miles	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	No.	No.	No.	Lin. Ft.	No.	No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Main Running:															
Exclusive passenger		160,925	24,362	35.09	168,771	16,516			16,516	15		4	865	14	2
Exclusive freight		717,398	7,850	137.36	619,145	104,420	1,683		106,103	364	13	107	19,770	37	77
Joint passenger and freight		1,224,274	120,990	254.78	1,248,110	91,514	5,640		97,154	397	12	116	22,872	75	57
Joint passenger and freight passing		16,051		3.04	13,888	1,603	560		2,163	7		2	380		
Totals		2,118,648	153,202	430.27	2,049,914	214,053	7,883		221,936	783	25	229	43,887	126	136
Other Running:															
Main and passing	21	85,163	4,625	17.01	81,628	3,600	3,590	970	8,160	44		10	1,880		3
Wye and other	104	148,172		28.06	91,328	21,157	21,484	14,203	56,844	97		14	2,670	7	2
Totals	125	233,335	4,625	45.07	172,956	24,757	25,074	15,173	65,004	141		24	4,550	7	5
Passenger Car Yard:															
Lead															
Ladder	2	1,196		0.23	1,000		196		196	8					
Double ladder †															
Work and storage	18	15,901		3.01	13,500		2,401		2,401	18					
Service and repair	0														
Totals	20	17,097		3.24	14,500		2,597		2,597	26					
Passenger Terminal Yard:															
Lead	None														
Ladder															
Double ladder †															
Passenger															
Baggage, mail, express, etc.															
Totals															
Freight Switching Yard:															
Lead	66	105,276		19.94	89,991	12,270	570	2,445	15,285	127	6	19	3,525		
Ladder	124	117,525		22.26	97,785	2,550	5,450	11,740	19,740	1,150	38	27	4,515		
Double ladder †	(7)	(4,935)		(0.94)											
Run-around	34	94,106		17.82	76,631	8,425	7,790	1,260	17,475	76	3	31	5,095		
Work and storage	900	1,902,998	13,150	362.91	1,630,695	26,715	108,098	150,640	285,453	339	21	83	14,379	3	
Service and repair	49	56,470		10.70	41,950	3,300	8,870	2,350	14,520	22		1	160		
Totals	1,173	2,276,375	13,150	433.63	1,937,052	53,260	130,778	168,435	352,473	1,714	68	161	27,674	3	
Freight Terminal Yard:															
Lead	None														
Ladder															
Double ladder †															
Service and storage															
Totals															
Team	45	42,440		8.04	30,890	1,990	6,050	3,510	11,550	20		1	180	1	
Totals	45	42,440		8.04	30,890	1,990	6,050	3,510	11,550	20		1	180	1	
Industrial:															
Owned by railroad company	302	263,489	750	50.05	175,820	6,149	57,941	24,326	88,419	134		7	1,310	5	3
Owned by industry	203	223,641	300	42.41	155,890	8,045	34,458	25,548	68,051	250	2	8	1,505		
Totals	505	487,130	1,050	92.46	331,710	14,194	92,402	49,874	156,470	384	2	15	2,815	5	3
Roundhouse:															
Service and storage	133	63,803		12.08	47,351	3,000	9,402	4,050	16,452	86	2	10	1,670		
Totals	133	63,803		12.08	47,351	3,000	9,402	4,050	16,452	86	2	10	1,670		
Shop:															
Lead	1	885		0.17	600		285		285	2					
Ladder	1	2,613		0.49	2,200		413		413	36					
Run-around															
Service and storage	38	41,342		7.83	34,200		7,142		7,142	10		3	522		
Totals	40	44,840		8.49	37,000		7,840		7,840	48		3	522		
Grand Totals	2,041	5,283,668	172,027	1,033.28	4,621,373	311,254	282,026	241,042	834,322	3,202	97	443	81,298	143	144

* Exclusive of crossovers.

† Double ladder tracks counted once under single ladder tracks, hence not included in totals.

TABLE CXXXVII. MILEAGE OF ALL CLASSES OF STEAM RAILROAD TRACK. ZONE B IN INDIANA
(Basis of 1912)

Kind of Tracks		Length			Alignment					Switches			Crossovers		Crossings			
						Curved Track									Owned			
	Tracks	Surface	Elevated	Total *	Tangent	0° to 6°	7° to 12°	13° and over	Total	Single	Single Slip	Double Slip	Total	Length	Scissors		Simple	Other
	No.	Lin. Ft.	Lin. Ft.	Miles	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	No.	No.	No.	No.	Lin. Ft.	No.	Lth.	No.	No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Main Running:																		
Exclusive passenger		153,365		29.05	124,975	28,390			28,390	29			14	3,530			20	
Exclusive freight		475,908	6,700	91.40	374,640	97,008	10,290	670	107,968	257		11	53	10,025			34	37
Joint passenger and freight		563,472		106.72	497,971	60,091	5,410		65,501	193	2		42	8,145			45	74
Joint passenger and freight passing		21,698		4.11	18,948	1,380	1,370		2,750	10			1	180			7	
Totals		1,214,443	6,700	231.28	1,016,534	186,869	17,070	670	204,609	489	2	11	110	21,880			106	111
Other Running:																		
Main and passing	16	80,840		15.31	63,480	12,100	1,460	3,800	17,360	26		3	5	1,205				
Wye and other	57	68,903		13.05	38,600	8,898	12,620	8,785	30,303	15			3	595			2	
Totals	73	149,743		28.36	102,080	20,998	14,080	12,585	47,663	41		3	8	1,800			2	
Passenger Car Yard:							None											
Lead																		
Ladder																		
Double ladder †																		
Work and storage																		
Service and repair																		
Totals																		
Passenger Terminal Yard:							None											
Lead																		
Ladder																		
Double ladder †																		
Passenger																		
Baggage, mail, express, etc																		
Totals																		
Freight Switching Yard:																		
Lead	48	100,020		18.94	75,140	14,850	4,840	5,190	24,880	83		5	16	3,340	1	180	2	
Ladder	94	79,830		15.12	56,780	3,020	3,210	16,820	23,050	707		10	3	605				
Double ladder †	(5)	(4,380)		(0.83)														
Run-around	15	49,090		9.30	40,460	2,780	3,920	1,930	8,630	37			2	355				
Work and storage	503	1,166,252		220.88	973,252	53,240	34,540	105,220	193,000	219		4	24	3,980				4
Service and repair	48	58,360		11.05	43,540	1,650	4,330	8,840	14,820	41			5	680			1	
Totals	708	1,453,552		275.29	1,189,172	75,540	50,840	138,000	264,380	1,087		19	50	8,960	1	180	3	4
Freight Terminal Yard:							None											
Lead																		
Ladder																		
Double ladder †																		
Service and storage																		
Totals																		
Team	21	17,730		3.36	13,090	220	2,530	1,890	4,640	1								
Totals	21	17,730		3.36	13,090	220	2,530	1,890	4,640	1								
Industrial:																		
Owned by railroad company	159	281,624		53.34	199,582	8,825	28,907	44,310	82,042	242		14	31	4,845	1	160	23	
Owned by industry	97	86,168		16.32	54,130	3,890	13,840	14,308	32,038	81							1	1
Totals	256	367,792		69.66	253,712	12.715	42,747	58,618	114,080	323		14	31	4,845	1	160	24	1
Roundhouse:																		
Service and storage	126	53,820		10.19	41,010	1,000	2,250	9,530	12,780	57		3	4	750				
Totals	126	53,820		10.19	41,040	1,000	2,250	9,530	12,780	57		3	4	750				
Shop:																		
Lead	2	1,900		0.36	1,770			130	130	3								
Ladder	3	2,100		0.40	1,450			650	650	23								
Run-around	0																	
Service and storage	40	40,020		7.58	31,880			8,140	8,140	25								
Totals	45	44,020		8.34	35,100			8,920	8,920	51								
Grand Totals	1,229	3,301,100	6,700	626.48	2,650,728	297,342	129,517	230,213	657,072	2,049	2	50	203	38,235	2	340	135	116

* Exclusive of crossovers. † Double ladder tracks counted once under single ladder tracks, hence not included in the totals.

TABLE CXXXVIII. MILEAGE OF STEAM RAILROAD TRACK. TOTALS BY RAILROADS. ZONES A AND B
(Basis of 1912)

Railroad	Tracks	Length				Alignment					Switches			Crossovers		Crossings			
		Surface	Elevated	Depressed	Total *	Tangent	Curved Track				Single	Single Slip	Double Slip	Total		Owned			Other
							0° to 6°	7° to 12°	13° and over	Total						Scissors		Simple	
	No.	Lin. Ft.	Lin.Ft.	Lin.Ft.	Miles	Lin.Ft.	Lin.Ft.	Lin.Ft.	Lin.Ft.	Lin.Ft.	No.	No.	No.	No.	Length	No.	Lth.	No.	No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Atchison, Topeka & Santa Fe Ry.	286	433,305	38,747		89.40	396,694	41,596	31,762	2,000	75,358	349		15	45	8,050			10	38
Baltimore & Ohio R. R.	224	447,810	20,780		88.75	346,045	75,725	10,885	35,935	122,545	306		2	37	6,845			29	18
Baltimore & Ohio Chicago Terminal R. R.	560	925,814	196,451		212.56	867,820	90,631	43,654	120,160	254,445	782		16	119	21,975	4	1,060	42	154
Calumet, Hammond & Southeastern R. R.	29	37,700			7.14	25,810	1,345	2,780	7,765	11,890	39			5	800				
Chesapeake & Ohio Ry. of Indiana	23	34,825			6.60	26,675	6,600	1,300	250	8,150	21								
Chicago & Alton R. R.	315	416,905	51,470		88.71	327,490	74,585	35,740	30,560	140.885	432		8	45	8,240			76	3
Chicago & Calumet River R. R.	10	15,736			2.98	11,316		2,450	1,970	4,420	18			5	800				
Chicago & Eastern Illinois R. R.	338	439,421	27,232		88.38	375,358	34,161	14,151	42,983	91,295	387		7	35	5,961				4
Chicago & Erie R. R.	173	184,388	105,695		54.94	223,271	10,166	14,186	42,460	66,812	276	2	2	9	1,765	1	180		12
Chicago & Illinois Western R. R.	44	87,965			16.66	65,840	7,545	14,580		22,125	72			7	1,260			7	2
Chicago & North Western Ry.	1,479	1,409,373	1,285,774		510.45	2,192,534	144,833	345,840	11,940	502,613	1,947	2	112	174	33,115	3	440	86	42
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	670	1,074,511	549,448		307.56	1,305,205	128,015	103,030	87,709	318,754	1,144	6	23	184	34,083	1	130	87	102
Chicago, Burlington & Quincy R. R.	778	804,493	305,105	6,750	211.44	890,453	46,580	38,030	141,285	225,895	1,136		7	87	17,580			50	30
Chicago Great Western R. R.	95	186,634			35.34	175,524	2,920	2,440	5,750	11,110	106			7	1,030			4	
Chicago, Indiana & Southern R. R.	267	542,881			102.82	406,055	51,011	11,692	74,123	136,826	385			24	5,255			2	36
Chicago, Indianapolis & Louisville Ry.	92	135,946			25.75	110,136	5,400	5,420	14,990	25,810	120			5	800			2	6
Chicago Junction Ry.	1,021	1,005,065	49,683		199.76	835,750	33,150	110,318	75,530	218,998	1,256		33	137	22,756	9	1,520	73	12
Chicago, Milwaukee & St. Paul Ry.	927	1,464,064	263,396		327.17	1,421,801	96,682	158,752	50,225	305,659	1,382		27	188	32,615	2	360	42	38
Chicago River & Indiana R. R.	36	54,298			10.28	35,458	7,558	7,152	4,130	18,840	63			10	1,720			4	
Chicago, Rock Island & Pacific Ry.	631	693,483	251,592		178.99	742,074	51,366	147,362	4,273	203,001	772		15	137	24,693			87	31
Chicago Short Line Ry.	26	21,723			4.11	15,873		5,850		5,850	30							4	6
Chicago Union Transfer Ry.	196	533,118			100.97	461,537	22,161	11,160	38,260	71,581	345		52	77	12,320			7	4
Chicago, West Pullman & Southern R. R.	50	83,197			15.76	41,400			41,797	41,797	114			8	1,280				
Elgin, Joliet & Eastern Ry.	1,063	1,611,261	15,745		308.15	1,226,261	100,000	101,270	199,475	400.745	1,593		74	134	21,890	2	320	48	24
Grand Trunk Western Ry.	192	414,125	37,162		85.47	368,218	19,740	38,170	25,159	83,069	262		1	33	6,319			19	9
Illinois Central R. R.	913	1,378,542	272,205	166,644	344.21	1,578,401	151,810	82,695	4,485	238,990	1,042	2	87	191	35,664	5	1,800	118	58
Illinois Northern Ry.	70	88,492			16.76	58,449	8,250	13,330	8,463	30,043	90			2	380			4	12
Indiana Harbor Belt R. R.	253	733,754	23,400		143.40	606,016	78,326	56,382	16,430	151,138	450		1	48	9,350			28	33
Lake Shore & Michigan Southern Ry.	399	477,050	477,965		180.88	736,855	129,840	76,875	11,445	218,160	701		30	121	24,590			54	4
Manufacturers' Junction Ry.	80	58,397	5,675		12.13	54,575		2,595	6,902	9,497	112			7	1,323				1
Michigan Central R. R.	202	423,630		29,988	85.91	368,002	26,730	33,926	24,960	85,616	314			40	8,375			40	
Minneapolis, St. Paul & Sault Ste. Marie Ry.	58	165,565			31.36	143,127	9,098	1,670	11,670	22,438	112			13	2,120			1	8
New York, Chicago & St. Louis R. R.	108	314,670			59.59	282,994	15,660	6,016	10,000	31,676	174		1	35	5,760			26	12
Pere Marquette R. R.	26	45,513			8.62	34,743			10,770	10,770	28								
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	393	585,701	123,081		134.24	509,088	90,806	16,488	2,400	109,694	476		8	66	12,138	1	408	77	30
Pittsburgh, Fort Wayne & Chicago Ry.	579	470,325	468,402		177.78	755,307	68,065	114,105	1,250	183,420	831	1	11	82	14,815			54	26
Pullman Railroad	46	69,907			13.24	43,180	10,420	7,107	9,200	26,727	85			10	1,680			2	
South Chicago & Southern R. R.†	157	341,450			64.66	238,170	57,230	43,130	2,920	103,280	242			25	4,412			9	21
Wabash Railroad	173	341,250	48,905		73.90	315,046	29,000	7,197	38,912	75,109	266		2	22	4,099			12	10
Totals	12,982	18,552,287	4,617,913	203,382	4,426.82	18,708,551	1,727,005	1,719,490	1,218,536	4,665,031	18,260	13	534	2,174	395,858	28	6,218	1,104	786

* Exclusive of crossovers. † Operated by the Pennsylvania R. R.

TABLE CXXXIX. MILEAGE OF STEAM RAILROAD TRACK. TOTALS BY RAILROADS. ZONE A. CITY OF CHICAGO*
(Basis of 1912)

Railroad	Tracks	Length				Alignment					Switches			Cross-overs		Crossings			
		Surface	Elevated	Depressed	Total *	Tangent	Curved Track				Single	Single Slip	Double Slip	Total	Length	Owned			Other
							0° to 6°	7° to 12°	15° and over	Total						Scissors		Simple	
	No.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Miles	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	No.	No.	No.	No.	Lin. Ft.	No.	Lth.	No.	No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Atchison, Topeka & Santa Fe Ry.	276	355,220	38,747		74.61	325,022	38,056	28,889	2,000	68,945	329		15	41	7,283			6	38
Baltimore & Ohio R. R.	140	201,295	20,780		42.06	148,025	44,510	10,685	18,855	74,050	185		1	28	5,155			20	12
Baltimore & Ohio Chicago Terminal R. R.	312	223,890	196,451		79.61	310,469	23,377	32,730	53,765	109,872	375		13	54	9,737	4	1,060	21	87
Calumet, Hammond & Southeastern R. R.	29	37,700			7.14	25,810	1,345	2,780	7,765	11,890	39			5	800				
Chesapeake & Ohio Ry. of Indiana																			
Chicago & Alton R. R.	240	228,245	51,470		52.98	171,770	61,105	24,990	21,850	107,945	329		8	42	7,735			68	3
Chicago & Calumet River R. R.	10	15,736			2.98	11,316		2,450	1,970	4,420	18			5	800				
Chicago & Eastern Illinois R. R.	88	82,765	27,232		20.83	88,187	4,709	8,951	8,150	21,810	88			12	1,920				
Chicago & Erie R. R.	95	26,660	105,695		25.07	98,285		9,880	24,190	34,070	165		2	1	275				
Chicago & Illinois Western R. R.																			
Chicago & North Western Ry.	1,267	806,180	1,170,842		374.44	1,570,119	123,957	276,401	6,545	406,903	1,635	2	102	154	29,315	3	440	85	42
Chicago & Western Indiana R. R. and the Belt Railway of Chicago	646	1,014,861	528,448		292.29	1,232,955	126,875	100,240	83,239	310,354	1,078	6	23	167	30,738	1	130	84	86
Chicago, Burlington & Quincy R. R.	555	388,740	305,105	6,750	132.69	516,485	46,190	30,720	107,200	184,110	802		7	59	11,100			49	30
Chicago Great Western R. R.	89	105,151			19.91	95,901	2,500	1,000	5,750	9,250	91			2	280				
Chicago, Indiana & Southern R. R.																			
Chicago, Indianapolis & Louisville Ry.	9	7,055			1.34	4,780			2,275	2,275	9			1	100				
Chicago Junction Ry.	1,021	1,005,065	49,683		199.76	835,750	33,150	110,318	75,530	218,998	1,256		33	137	22,756	9	1,520	73	12
Chicago, Milwaukee & St. Paul Ry.	784	934,483	240,976		222.62	940,224	75,902	124,808	34,525	235,235	1,144		11	137	24,155	2	360	34	38
Chicago River & Indiana R. R.	36	54,298			10.28	35,458	7,558	7,152	4,130	18,840	63			10	1,720			4	
Chicago, Rock Island & Pacific Ry.	467	374,423	251,592		118.56	483,085	36,070	102,587	4,273	142,930	559		10	108	19,461			87	31
Chicago Short Line Ry.	26	21,723			4.11	15,873		5,850		5,850	30							4	6
Chicago Union Transfer Ry.	11	35,461			6.72	27,336	8,125			8,125	22							6	4
Chicago, West Pullman & Southern R. R.	50	83,197			15.76	41,400			41,797	41,797	114			8	1,280				
Elgin, Joliet & Eastern Ry.	683	620,650	9,015		119.26	412,410	28,665	71,050	117,570	217,285	891		26	52	8,435	1	160	27	6
Grand Trunk Western Ry.	152	241,023	37,162		52.69	226,611		32,052	19,522	51,574	189		1	19	3,757			4	4
Illinois Central R. R.	840	1,140,561	264,205	166,644	297.62	1,366,235	134,949	65,741	4,485	205,175	896	2	86	164	30,374	5	1,800	92	50
Illinois Northern Ry.	70	88,492			16.76	58,449	8,250	13,330	8,463	30,043	90			2	380			4	12
Indiana Harbor Belt R. R.	6	53,935	23,400		14.65	71,620	3,545	1,515	655	5,715	24			4	560				
Lake Shore & Michigan Southern Ry.	337	91,355	477,965		107.83	431,240	71,605	55,030	11,445	138,080	535		29	93	18,120			32	4
Manufacturers' Junction Ry.	1	3,300			0.63	1,200		2,100		2,100	5								
Michigan Central R. R.	181	249,497		29,988	52.93	211,469	15,480	32,016	20,520	68,016	267			28	5,855			6	
Minneapolis, St. Paul & Sault Ste. Marie Ry.																			
New York, Chicago & St. Louis R. R.	98	225,036			42.62	197,746	11,860	5,430	10,000	27,290	134		1	28	4,400			8	4
Pere Marquette R. R.																			
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	365	485,669	123,081		115.29	506,156	86,306	14,188	2,100	102,594	441		6	61	11,363	1	408	64	21
Pittsburgh, Fort Wayne & Chicago Ry.	515	223,620	468,402		131.06	540,457	53,490	96,825	1,250	151,565	710	1	11	65	11,540			38	20
Pullman Railroad	46	69,907			13.24	43,180	10,420	7,107	9,200	26,727	85			10	1,680			2	
South Chicago & Southern R. R.‡	97	199,645			37.81	134,380	41,010	23,935	320	65,265	153			14	2,312			1	6
Wabash Railroad	170	272,681	48,905		60.91	257,047	19,400	7,197	37,942	64,539	258		2	17	2,939			8	10
Totals	9,712	9,967,519	4,439,186	203,382	2,767.06	11,436,450	1,118,400	1,307,947	747,281	3,173,637	13,009	11	387	1,528	276,325	26	5,878	827	526

* Does not include Morgan Park. † Exclusive of crossovers. ‡ Operated by the Pennsylvania R. R.

TABLE CXL. MILEAGE OF STEAM RAILROAD TRACK. TOTALS BY RAILROADS. ZONE B IN ILLINOIS AND INDIANA
(Basis of 1912)

Railroad	Tracks	Length			Alignment					Switches			Crossovers		Crossings			
		Surface	Elevated	Total*	Tangent	Curved Track				Single	Single Slip	Double Slip	Total	Length	Owned			Other
						0° to 6°	7° to 12°	13° and over	Total						Scissors		Simple	
	No.	Lin.Ft.	Lin.Ft.	Miles	Lin.Ft.	Lin.Ft.	Lin.Ft.	Lin.Ft.	Lin.Ft.	No.	No.	No.	No.	Lin. Ft.	No.	Lth.	No.	No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Atchison, Topeka & Santa Fe Ry.	10	78,085		14.79	71,672	3,540	2,873		6,413	20			4	767			4	
Baltimore & Ohio R. R.	84	246,515		46.69	198,020	31,215	200	17,080	48,495	121		1	9	1,690			9	6
Baltimore & Ohio Chicago Terminal R. R.	248	701,924		132.95	557,351	67,254	10,924	66,395	144,573	407		3	65	12,238			21	67
Calumet, Hammond & Southeastern R. R.																		
Chesapeake & Ohio Ry. of Indiana	23	34,825		6.60	26,675	6,600	1,300	250	8,150	21								
Chicago & Alton R. R.	75	188,660		35.73	155,720	13,480	10,750	8,710	32,940	103			3	505			8	
Chicago & Calumet River R. R.																		
Chicago & Eastern Illinois R. R.	250	356,656		67.55	287,171	29,452	5,200	34,833	69,485	299		7	23	4,041				4
Chicago & Erie R. R.	78	157,728		29.87	124,986	10,166	4,306	18,270	32,742	111	2		8	1,490	1	180		12
Chicago & Illinois Western R. R.	44	87,965		16.66	65,840	7,545	14,580		22,125	72			7	1,260			7	2
Chicago & North Western Ry.	212	603,193	114,932	136.01	622,415	20,876	69,439	5,395	95,710	312		10	20	3,800			1	
Chicago & Western Indiana R. R. and the Belt Railway of Chicago	24	59,650	21,000	15.27	72,250	1,140	2,790	4,470	8,400	66			17	3,345			3	16
Chicago, Burlington & Quincy R. R.	223	415,753		78.75	373,968	390	7,310	34,085	41,785	334			28	6,480			1	
Chicago Great Western R. R.	6	81,483		15.43	79,623	420	1,440		1,860	15			5	750			4	
Chicago, Indiana & Southern R. R.	267	542,881		102.82	406,055	51,011	11,692	74,123	136,826	385			24	5,255			2	36
Chicago, Indianapolis & Louisville Ry.	83	128,891		24.41	105,356	5,400	5,420	12,715	23,535	111			4	700			2	6
Chicago Junction Ry.																		
Chicago, Milwaukee & St. Paul Ry.	143	529,581	22,420	104.55	481,577	20,780	33,944	15,700	70,424	238		16	51	8,460			8	
Chicago River & Indiana R. R.																		
Chicago, Rock Island & Pacific Ry.	104	319,060		60.43	258,989	15,296	44,775		60,071	213		5	29	5,232				
Chicago Short Line Ry.																		
Chicago Union Transfer Ry.	185	497,657		94.25	434,201	14,036	11,160	38,260	63,456	323		52	77	12,320			1	
Chicago, West Pullman & Southern R. R.																		
Elgin, Joliet & Eastern Ry.	380	990,611	6,700	188.89	813,851	71,335	30,220	81,905	183,460	702		48	82	13,455	1	160	21	18
Grand Trunk Western Ry.	40	173,102		32.78	141,607	19,740	6,118	5,637	31,495	73			14	2,562			15	5
Illinois Central R. R.	73	237,981	8,000	46.59	212,166	16,861	16,954		33,815	146		1	27	5,290			26	8
Illinois Northern Ry.																		
Indiana Harbor Belt R. R.	247	679,819		128.75	534,396	74,781	54,867	15,775	145,423	426		1	44	8,790			28	33
Lake Shore & Michigan Southern Ry.	62	385,695		73.05	305,615	58,235	21,845		80,080	166		1	28	6,470			22	
Manufacturers' Junction Ry.	79	55,097	5,675	11.50	53,375		495	6,902	7,397	107			7	1,323				1
Michigan Central R. R.	21	174,133		32.98	156,533	11,250	1,910	4,440	17,600	47			12	2,520			34	
Minneapolis, St. Paul & Sault Ste. Marie Ry.	58	165,565		31.36	143,127	9,098	1,670	11,670	22,438	112			13	3,120			1	8
New York, Chicago & St. Louis R. R.	10	89,634		16.97	85,248	3,800	586		4,386	40			7	1,360			18	8
Pere Marquette R. R.	26	45,513		8.62	34,743			10,770	10,770	28								
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	28	100,032		18.95	92,932	4,500	2,300	300	7,100	35		2	5	775			13	9
Pittsburgh, Fort Wayne & Chicago Ry.	64	246,705		46.72	214,850	14,575	17,280		31,855	121			17	3,275			16	6
Pullman Railroad																		
South Chicago & Southern R. R. †	60	141,805		26.85	103,790	16,220	19,195	2,600	38,015	89			11	2,100			8	15
Wabash Railroad	3	68,569		12.99	57,999	9,600		970	10,570	8			5	1,160			4	
Totals	3,270	8,584,768	178,727	1,659.76	7,272,101	608,596	411,543	471,255	1,491,394	5,251	2	147	646	119,533	2	340	277	260

* Exclusive of crossovers. † Operated by the Pennsylvania R. R.

TABLE CXLI. MILEAGE OF STEAM RAILROAD TRACK. TOTALS BY RAILROADS. ZONE B IN ILLINOIS
(Basis of 1912)

Railroad	Tracks	Length			Alignment					Switches		Crossovers		Crossings	
						Curved Track									
		Surface	Elevated	Total*	Tangent	0° to 6°	7° to 12°	13° and over	Total	Single	Double Slip	Total	Length	Owned Simple	Other
	No.	Lin.Ft.	Lin.Ft.	Miles	Lin.Ft.	Lin.Ft.	Lin.Ft.	Lin.Ft.	Lin.Ft.	No.	No.	No.	Lin.Ft.	No.	No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Atchison, Topeka & Santa Fe Ry.	10	78,085		14.79	71,672	3,540	2,873		6,413	20		4	767	4	
Baltimore & Ohio R. R.															
Baltimore & Ohio Chicago Terminal R. R.	176	533,147		100.98	411,604	61,484	10,414	49,645	121,543	294	3	51½	9,768	9	49
Calumet, Hammond & Southeastern R. R.															
Chesapeake & Ohio Ry. of Indiana															
Chicago & Alton R. R.	75	188,660		35.73	155,720	13,480	10,750	8,710	32,940	103		3	505	8	
Chicago & Calumet River R. R.															
Chicago & Eastern Illinois R. R.	250	356,656		67.55	287,171	29,452	5,200	34,833	69,485	299	7	23	4,041		4
Chicago & Erie R. R.															
Chicago & Illinois Western R. R.	44	87,965		16.66	65,840	7,545	14,580		22,125	72		7	1,260	7	2
Chicago & North Western Ry.	212	603,193	114,932	136.01	622,415	20,876	69,439	5,395	95,710	312	10	20	3,800	1	
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	24	59,650	21,000	15.27	72,250	1,140	2,790	4,470	8,400	66		17	3,345	3	16
Chicago, Burlington & Quincy R. R.	223	415,753		78.75	373,968	390	7,310	34,085	41,785	334		28	6,480	1	
Chicago Great Western R. R.	6	81,483		15.43	79,623	420	1,440		1,860	15		5	750	4	
Chicago, Indiana & Southern R. R.															
Chicago, Indianapolis & Louisville Ry.															
Chicago Junction Ry.															
Chicago, Milwaukee & St. Paul Ry.	143	529,581	22,420	104.55	481,577	20,780	33,944	15,700	70,424	238	16	51	8,460	8	
Chicago River & Indiana R. R.															
Chicago, Rock Island & Pacific Ry.	164	319,060		60.43	258,989	15,296	44,775		60,071	213	5	29	5,232		
Chicago Short Line Ry.															
Chicago Union Transfer Ry.	185	497,657		94.25	434,201	14,036	11,160	38,260	63,456	323	52	77	12,320	1	
Chicago, West Pullman & Southern R. R.															
Elgin, Joliet & Eastern Ry.	13	40,435		7.66	37,315			3,120	3,120	20					
Grand Trunk Western Ry.	40	173,102		32.78	141,607	19,740	6,118	5,637	31,495	73		14	2,562	15	5
Illinois Central R. R.	73	237,981	8,000	46.59	212,166	16,861	16,954		33,815	146	1	27	5,290	26	8
Illinois Northern Ry.															
Indiana Harbor Belt R. R.	180	527,100		99.83	430,986	55,456	34,458	6,200	96,114	324	1	43	8,590	21	31
Lake Shore & Michigan Southern Ry.															
Manufacturers' Junction Ry.	79	55,097	5,675	11.50	53,375		495	6,902	7,397	107		7	1,323		1
Michigan Central R. R.	17	76,078		14.41	66,218	4,400	1,910	3,550	9,860	35		9	1,900	8	
Minneapolis, St. Paul & Sault Ste. Marie Ry.	58	165,565		31.36	143,127	9,098	1,670	11,670	22,438	112		13½	2,120	1	8
New York, Chicago & St. Louis R. R.	2	24,434		4.62	23,848		586		586	10		3	480	7	
Pere Marquette R. R.	26	45,513		8.62	34,743			10,770	10,770	28					
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	28	100,032		18.95	92,932	4,500	2,300	300	7,100	35	2	5	775	13	9
Pittsburgh, Fort Wayne & Chicago Ry.															
Pullman Railroad															
South Chicago & Southern R. R. †	10	39,720		7.52	30,375	5,660	2,860	825	9,345	17		2	370	1	11
Wabash Railroad	3	47,721		9.04	39,651	7,100		970	8,070	6		4	1,160	4	
Totals	2,041	5,283,668	172,027	1,033.28	4,621,373	311,254	282,026	241,042	834,322	3,202	97	443	81,298	142	144

* Exclusive of crossovers. † Operated by the Pennsylvania R. R.

TABLE CXLII. MILEAGE OF STEAM RAILROAD TRACK. TOTALS BY RAILROADS. ZONE B IN INDIANA
(Basis of 1912)

Railroad	Tracks	Length			Alignment					Switches			Crossovers		Crossings			
						Curved Track									Owned			
		Surface	Elevated	Total *	Tangent	0° to 6°	7° to 12°	13° and over	Total	Single	Single Slip	Double Slip	Total	Length	Scissors		Simple	Other
	No.	Lin.Ft.	Lin.Ft.	Miles	Lin.Ft.	Lin.Ft.	Lin.Ft.	Lin.Ft.	Lin.Ft.	No.	No.	No.	No.	Lin.Ft.	No.	Lth.	No.	No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Atchison, Topeka & Santa Fe Ry.																		
Baltimore & Ohio R. R.	84	246,515		46.69	198,020	31,215	200	17,080	48,495	121		1	9	1,690			9	6
Baltimore & Ohio Chicago Terminal R. R.	72	168,777		31.97	145,747	5,770	510	16,750	23,030	113			13	2,470			12	18
Calumet, Hammond & Southeastern R. R.																		
Chesapeake & Ohio Ry. of Indiana	23	34,825		6.60	26,675	6,600	1,300	250	8,150	21								
Chicago & Alton R. R.																		
Chicago & Calumet River R. R.																		
Chicago & Eastern Illinois R. R.																		
Chicago & Erie R. R.	78	157,728		29.87	124,986	10,166	4,306	18,270	32,742	111	2		8½	1,490	1	180		12
Chicago & Illinois Western R. R.																		
Chicago & North Western Ry.																		
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago																		
Chicago, Burlington & Quincy R. R.																		
Chicago Great Western R. R.																		
Chicago, Indiana & Southern R. R.	267	542,881		102.82	406,055	51,011	11,692	74,123	136,826	385			24	5,255			2	36
Chicago, Indianapolis & Louisville Ry	83	128,891		24.41	105,356	5,400	5,420	12,715	23,535	111			4	700			2	6
Chicago Junction Ry.																		
Chicago, Milwaukee & St. Paul Ry.																		
Chicago River & Indiana R. R.																		
Chicago, Rock Island & Pacific Ry.																		
Chicago Short Line Ry.																		
Chicago Union Transfer Ry.																		
Chicago, West Pullman & Southern R. R.																		
Elgin, Joliet & Eastern Ry.	367	950,176	6,700	181.23	776,536	71,335	30,220	78,785	180,340	682		48	82	13,455	1	160	21	18
Grand Trunk Western Ry.																		
Illinois Central R. R.																		
Illinois Northern Ry.																		
Indiana Harbor Belt R. R.	67	152,719		28.92	103,410	19,325	20,409	9,575	49,309	102			1	200			7	2
Lake Shore & Michigan Southern Ry.	62	385,695		73.05	305,615	58,235	21,845		80,080	166		1	27½	6,470			22	
Manufacturers' Junction Ry.																		
Michigan Central R. R.	4	98,055		18.57	90,315	6,850		890	7,740	12			3	620			26	
Minneapolis, St. Paul & Sault Ste. Marie Ry.																		
New York, Chicago & St. Louis R. R.	8	65,200		12.35	61,400	3,800			3,800	30			5½	880			11	3
Pere Marquette R. R.																		
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.																		
Pittsburgh, Fort Wayne & Chicago Ry.	64	246,705		46.72	214,850	14,575	17,280		31,855	121			16½	3,275			16	6
Pullman Railroad																		
South Chicago & Southern R. R. †	50	102,085		19.33	73,415	10,560	16,335	1,775	28,670	72			9	1,730			7	4
Wabash Railroad		20,848		3.95	18,348	2,500			2,500	2								
Totals	1,229	3,301,100	6,700	626.48	2,650,728	297,342	129,517	230,213	657,072	2,049	2	50	203	38,235	2	340	135	116

* Exclusive of crossovers. † Operated by the Pennsylvania R. R.

TABLE CXLIII. MILEAGE OF STEAM RAILROAD TRACK. SUMMARY OF SURFACE, ELEVATED AND DEPRESSED TRACK, BY ROADS. ZONES A AND B

(Basis of 1912)

Railroad	Surface Track				Elevated Track				Depressed Track				Miles	Per Cent of Total Track Zones A & B	Per Cent of Track in Cross-overs
	Lineal Feet	Per Cent of Surface Track Zones A & B	Per Cent of Total Track Zones A & B	Per Cent of Co.'s Track Zones A & B	Lineal Feet	Per Cent of Elevated Track Zones A & B	Per Cent of Total Track Zones A & B	Per Cent of Co.'s Track Zones A & B	Lineal Feet	Per Cent of Depressed Track Zones A & B	Per Cent of Total Track Zones A & B	Per Cent of Co.'s Track Zones A & B			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Atchison, Topeka & Santa Fe Ry.	433,305	2.33	1.82	90.25	38,747	0.84	0.16	8.10					89.40	1.98	1.65
Baltimore & Ohio R. R.	447,810	2.41	1.88	94.19	20,780	0.45	0.08	4.37					88.75	1.96	1.44
Baltimore & Ohio Chicago Terminal R. R.	925,814	4.99	3.89	80.91	196,451	4.25	0.83	17.17					212.56	4.72	1.92
Calumet, Hammond & Southeastern R. R.	37,700	0.20	0 16	97.92									7.14	0.16	2.08
Chesapeake & Ohio Ry. of Indiana	34,825	0.19	0.15	100.00									6.60	0.15	0.00
Chicago & Alton R. R.	416,905	2.25	1.75	87.47	51,470	1.11	0.22	10.80					88.71	1.97	1.73
Chicago & Calumet River R. R.	15,736	0.08	0.07	95.16									2.98	0.07	4.84
Chicago & Eastern Illinois R. R.	439,421	2.37	1.85	92.98	27,232	0.59	0.12	5.76					88.38	1.97	1.26
Chicago & Erie R. R.	184,388	1.00	0.78	63.18	105,695	2.29	0.44	36.22					54.94	1.22	0.60
Chicago & Illinois Western R. R.	87,965	0.47	0.37	98.59									16.66	0.37	1.41
Chicago & North Western Ry.	1,409,373	7.61	5.93	51.66	1,285,774	27.85	5.41	47.13					510.45	11.34	1.21
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	1,074,511	5.79	4.52	64.81	549,448	11.90	2.31	33.14					307.56	6.83	2.05
Chicago, Burlington & Quincy R. R.	804,493	4.34	3.38	70.95	305,105	6.61	1.28	26.91	6,750	3.32	0.03	0.59	211.44	4.69	1.55
Chicago Great Western R. R.	186,634	1.01	0.79	99.45									35.34	0.79	0.55
Chicago, Indiana & Southern R. R.	542,881	2.93	2.28	99.04									102.82	2.28	0.96
Chicago, Indianapolis & Louisville Ry.	135,946	0.73	0 57	99.41									25.75	0.57	0.59
Chicago Junction Ry.	1,005,065	5.42	4.23	93.28	49,683	1.07	0.21	4.61					199.76	4.44	2.11
Chicago, Milwaukee & St. Paul Ry.	1,464,064	7.90	6.16	83.18	263,396	5.70	1.11	14.97					327.17	7.27	1.85
Chicago River & Indiana R. R.	54,298	0.29	0.23	96.93									10.28	0.23	3.07
Chicago, Rock Island & Pacific Ry.	693,483	3.74	2.92	71.51	251,592	5.45	1.06	25.94					178.99	3.98	2.55
Chicago Short Line Ry.	21,723	0.12	0.09	100.00									4.11	0.09	0.00
Chicago Union Transfer Ry.	533,118	2.87	2.24	97.74									100.97	2.24	2.26
Chicago, West Pullman & Southern R. R.	83,197	0.45	0.35	98.48									15.76	0.35	1.52
Elgin, Joliet & Eastern Ry.	1,611,261	8.69	6.78	97.72	15,745	0.34	0.06	0.95					308.15	6.84	1.33
Grand Trunk Western Ry.	414,125	2.23	1.74	90.50.	37,162	0.80	0.16	8.12					85.47	1.90	1.38
Illinois Central R. R.	1,378,542	7.44	5.80	74.39	272,205	5.89	1.15	14.69	166,644	81.94	0.70	8.99	344.21	7.65	1.93
Illinois Northern Ry.	88,492	0.48	0.37	99.57									16.76	0.37	0.43
Indiana Harbor Belt R. R.	733,754	3.95	3.09	95.73	23,400	0.51	0.10	3.05					143.40	3.19	1.22
Lake Shore & Michigan Southern Ry.	477,050	2.57	2.01	48.70	477,965	10.36	2.01	48.79					180.88	4.02	2.51
Manufacturers' Junction Ry.	58,397	0.31	0.25	89.30	5,675	0.12	0.02	8.68					12.13	0.27	2.02
Michigan Central R. R.	423,630	2.28	1.77	91.70					29,988	14.74	0.13	6.49	85.91	1.90	1.81
Minneapolis, St. Paul & Sault Ste. Marie Ry.	165,565	0.89	0.70	98.74									31.36	0.70	1.26
New York, Chicago & St. Louis R. R.	314,670	1.67	1.32	98.20									59.59	1.32	1.80
Pere Marquette R. R.	45,513	0.25	0.19	100.00									8.62	0.19	0.00
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	585,701	3.16	2.46	81.24	123,081	2.67	0.52	17.07					134.24	2.98	1.69
Pittsburgh, Fort Wayne & Chicago Ry.	470,325	2.53	1.98	49.32	468,402	10.14	1.97	49.13					177.78	3.95	1.55
Pullman Railroad	69,907	0.38	0.29	97.66									13.24	0.29	2.34
South Chicago & Southern R. R.*	341,450	1.84	1.44	98.72									64.66	1.44	1.28
Wabash Railroad	341,250	1.84	1.44	86.56	48,905	1.06	0.21	12.40					73.90	1.65	1.04
Crossovers, all railroads													74.97	1.67	
Totals	18,552,287	100.00	78.04		4,617,913	100.00	19.43		203,382	100.00	0.86		4,501.79	100.00	

* Operated by the Pennsylvania R. R.

TABLE CXLIV. MILEAGE OF STEAM RAILROAD TRACK. SUMMARY OF SURFACE, ELEVATED AND DEPRESSED TRACK, BY ROADS. ZONE A, CITY OF CHICAGO
(Basis of 1912)

Railroad	Surface Track				Elevated Track				Depressed Track				Miles	Per Cent of Total Track in Chicago	Per Cent of Track in Cross-overs
	Lineal Feet	Per Cent of Surface Track in Chicago	Per Cent of Total Track in Chicago	Per Cent of Co.'s Track in Chicago	Lineal Feet	Per Cent of Elevated Track in Chicago	Per Cent of Total Track in Chicago	Per Cent of Co.'s Track in Chicago	Lineal Feet	Per Cent of Depressed Track in Chicago	Per Cent of Total Track in Chicago	Per Cent of Co.'s Track in Chicago			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Atchison, Topeka & Santa Fe Ry.	355,220	3.56	2.39	88.50	38,747	0.87	0.26	9.65					74.61	2.65	1.85
Baltimore & Ohio R. R.	201,295	2.02	1.35	88.58	20,780	0.47	0.14	9.15					42.06	1.49	2.27
Baltimore & Ohio Chicago Terminal R. R.	223,890	2.25	1.50	52.07	196,451	4.43	1.32	45.67					79.61	2.82	2.26
Calumet, Hammond & Southeastern R. R.	37,700	0.38	0.25	97.92									7.14	0.25	2.08
Chesapeake & Ohio Ry. of Indiana															
Chicago & Alton R. R.	228,245	2.29	1.53	79.41	51,470	1.16	0.35	17.91					52.98	1.88	2.68
Chicago & Calumet River R. R.	15,736	0.16	0.11	95.18									2.98	0.11	4.82
Chicago & Eastern Illinois R. R.	82,765	0.83	0.56	73.96	27,232	0.61	0.18	24.33					20.83	0.74	1.71
Chicago & Erie R. R.	26,660	0.27	0.18	20.10	105,695	2.38	0.71	79.69					25.07	0.89	0.21
Chicago & Illinois Western R. R.															
Chicago & North Western Ry.	806,180	8.09	5.42	40.22	1,170,842	26.37	7.86	58.41					374.44	13.28	1.37
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	1,014,861	10.18	6.82	64.47	528,448	11.90	3.55	33.58					292.29	10.37	1.95
Chicago, Burlington & Quincy R. R.	388,740	3.90	2.61	54.62	305,105	6.87	2.05	42.88	6,750	3.32	0.05	0.95	132.69	4.71	1.55
Chicago Great Western R. R.	105,151	1.06	0.71	99.73									19.91	0.71	0.27
Chicago, Indiana & Southern R. R.															
Chicago, Indianapolis & Louisville Ry.	7,055	0.07	0.05	98.60									1.34	0.05	1.40
Chicago Junction Ry.	1,005,065	10.08	6.75	93.30	49,683	1.12	0.34	4.60					199.76	7.09	2.10
Chicago, Milwaukee & St. Paul Ry.	934,483	9.37	6.28	77.90	240,976	5.43	1.62	20.09					223.62	7.90	2.01
Chicago River & Indiana R. R.	54,298	0.54	0.37	96.93									10.28	0.37	3.07
Chicago, Rock Island & Pacific Ry.	374,423	3.76	2.51	58.00	251,592	5.67	1.69	38.98					118.56	4.20	3.02
Chicago Short Line Ry.	21,723	0.22	0.15	100.00									4.11	0.15	0.00
Chicago Union Transfer Ry.	35,461	0.36	0.24	100.00									6.72	0.24	0.00
Chicago, West Pullman & Southern R. R.	83,197	0.83	0.56	98.49									15.76	0.56	1.51
Elgin, Joliet & Eastern Ry.	620,650	6.23	4.17	97.26	9,045	0.20	0.06	1.42					119.26	4.23	1.32
Grand Trunk Western Ry.	241,023	2.42	1.62	85.49	37,162	0.84	0.25	13.18					52.69	1.87	1.33
Illinois Central R. R.	1,140,561	11.44	7.66	71.20	264,205	5.95	1.77	16.50	166,644	81.94	1.12	10.40	297.62	10.55	1.90
Illinois Northern Ry.	88,492	0.89	0.59	99.57									16.76	0.59	0.43
Indiana Harbor Belt R. R.	53,935	0.54	0.36	69.25	23,400	0.53	0.16	30.04					14.65	0.52	0.71
Lake Shore & Michigan Southern Ry.	91,355	0.92	0.61	15.55	477,965	10.78	3.21	81.37					107.83	3.82	3.08
Manufacturers' Junction Ry.	3,300	0.03	0.02	100.00									0.63	0.02	0.00
Michigan Central R. R.	249,497	2.50	1.68	87.44					29,988	14.74	0.20	10.51	52.93	1.88	2.05
Minneapolis, St. Paul & Sault Ste. Marie Ry.															
New York, Chicago & St. Louis R. R.	225,036	2.26	1.51	98.08									42.62	1.51	1.92
Pere Marquette R. R.															
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	485,669	4.87	3.26	78.32	123,081	2.77	0.82	19.85					115.29	4.08	1.83
Pittsburgh, Fort Wayne & Chicago Ry.	223,620	2.24	1.50	31.78	468,402	10.55	3.15	66.58					131.06	4.65	1.64
Pullman Railroad	69,907	0.70	0.47	97.65									13.24	0.47	2.35
South Chicago & Southern R. R.*	199,645	2.00	1.34	98.86									37.81	1.34	1.14
Wabash Railroad	272,081	2.74	1.83	84.02	48,905	1.10	0.33	15.07					60.91	2.16	0.91
Crossovers, all railroads													52.33	1.85	
Totals	9,967,519	100.00	66.96		4,439,186	100.00	29.82		203,382	100.00	1.37		2,819.39	100.00	

* Operated by the Pennsylvania R. R.

TABLE CXLV. MILEAGE OF STEAM RAILROAD TRACK. SUMMARY OF SURFACE, ELEVATED AND DEPRESSED TRACK, BY ROADS. ZONE B IN ILLINOIS AND INDIANA
(Basis of 1912)

Railroad	Surface Track				Elevated Track				Depressed Track				Miles	Per Cent of Total Track in Zone B	Per Cent of Track in Cross-overs
	Lineal Feet	Per Cent of Surface Track in Zone B	Per Cent of Total Track in Zone B	Per Cent of Co.'s Track in Zone B	Lineal Feet	Per Cent of Elevated Track in Zone B	Per Cent of Total Track in Zone B	Per Cent of Co.'s Track in Zone B	Lineal Feet	Per Cent of Depressed Track in Zone B	Per Cent of Total Track in Zone B	Per Cent of Co.'s Track in Zone B			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Atchison, Topeka & Santa Fe Ry.	78,085	0.91	0.88	99.03									14.79	0.88	0.97
Baltimore & Ohio R. R.	246,515	2.87	2.77	99.32									46.69	2.77	0.68
Baltimore & Ohio Chicago Terminal R. R.	701,924	8.18	7.90	98.29									132.95	7.90	1.71
Calumet, Hammond & Southeastern R. R.															
Chesapeake & Ohio Ry. of Indiana	34,825	0.40	0.39	100.00									6.60	0.39	0.00
Chicago & Alton R. R.	188,660	2.20	2.12	99.73									35.73	2.12	0.27
Chicago & Calumet River R. R.															
Chicago & Eastern Illinois R. R.	356,656	4.15	4.01	98.88									67.55	4.01	1.12
Chicago & Erie R. R.	157,728	1.84	1.78	99.07									29.87	1.78	0.93
Chicago & Illinois Western R. R.	87,965	1.02	0.99	98.59									16.66	0.99	1.41
Chicago & North Western Ry.	603,193	7.03	6.80	83.55	114,932	64.30	1.29	15.92					136.01	8.09	0.53
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	59,650	0.69	0.67	71.02	21,000	11.75	0.24	25.00					15.27	0.91	3.98
Chicago, Burlington & Quincy R. R.	415,753	4.84	4.68	98.46									78.75	4.68	1.54
Chicago Great Western R. R.	81,483	0.95	0.92	99.08									15.43	0.92	0.92
Chicago, Indiana & Southern R. R.	542,881	6.32	6.11	99.04									102.82	6.11	0.96
Chicago, Indianapolis & Louisville Ry.	128,891	1.50	1.45	99.46									24.41	1.45	0.54
Chicago Junction Ry.															
Chicago, Milwaukee & St. Paul Ry.	529,581	6.17	5.96	94.50	22,420	12.55	0.25	4.00					104.55	6.21	1.50
Chicago River & Indiana R. R.															
Chicago, Rock Island & Pacific Ry.	319,060	3.72	3.59	98.39									60.43	3.59	1.61
Chicago Short Line Ry.															
Chicago Union Transfer Ry.	497,657	5.80	5.60	97.58									94.25	5.60	2.42
Chicago, West Pullman & Southern R. R.															
Elgin, Joliet & Eastern Ry.	990,611	11.55	11.15	98.00	6,700	3.75	0.08	0.67					188.89	11.23	1.33
Grand Trunk Western Ry.	173,102	2.02	1.95	98.54									32.78	1.95	1.46
Illinois Central R. R.	237,981	2.77	2.68	94.71	8,000	4.48	0.09	3.18					46.59	2.77	2.11
Illinois Northern Ry.															
Indiana Harbor Belt R. R.	679,819	7.92	7.65	98.72									128.75	7.65	1.28
Lake Shore & Michigan Southern Ry.	385,695	4.49	4.34	98.35									73.05	4.34	1.65
Manufacturers' Junction Ry.	55,097	0.64	0.63	88.74	5,675	3.17	0.06	9.14					11.50	0.69	2.12
Michigan Central R. R.	174,133	2.03	1.96	98.57									32.98	1.96	1.43
Minneapolis, St. Paul & Sault Ste. Marie Ry.	165,565	1.93	1.86	98.74									31.36	1.86	1.26
New York, Chicago & St. Louis R. R.	89,634	1.04	1.01	98.50									16.97	1.01	1.50
Pere Marquette R. R.	45,513	0.53	0.51	100.00									8.62	0.51	0.00
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	100,032	1.17	1.13	99.23									18.95	1.13	0.77
Pittsburgh, Fort Wayne & Chicago Ry.	246,705	2.87	2.78	98.69									46.72	2.78	1.31
Pullman Railroad															
South Chicago & Southern R. R.*	141,805	1.65	1.60	98.54									26.85	1.60	1.46
Wabash Railroad	68,569	0.80	0.77	98.34									12.99	0.77	1.66
Crossovers, all railroads													22.64	1.35	
Totals	8,584,768	100.00	96.64		178,727	100.00	2.01						1,682.40	100.00	

* Operated by the Pennsylvania R. R.

TABLE CXLVI. MILEAGE OF STEAM RAILROAD TRACK. SUMMARY OF SURFACE, ELEVATED AND DEPRESSED TRACK, BY ROADS. ZONE B IN ILLINOIS
(Basis of 1912)

Railroad	Surface Track				Elevated Track				Depressed Track				Miles	Per Cent of Total Track in Zone B-Ill.	Per Cent of Track in Cross-overs
	Lineal Feet	Per Cent of Surface Track in Zone B-Ill.	Per Cent of Total Track in Zone B-Ill.	Per Cent of Co.'s Track in Zone B-Ill.	Lineal Feet	Per Cent of Elevated Track in Zone B-Ill.	Per Cent of Total Track in Zone B-Ill.	Per Cent of Co.'s Track in Zone B-Ill.	Lineal Feet	Per Cent of Depressed Track in Zone B-Ill.	Per Cent of Total Track in Zone B-Ill.	Per Cent of Co.'s Track in Zone B-Ill.			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Atchison, Topeka & Santa Fe Ry.	78,085	1.48	1.41	99.03									14.79	1.41	0.97
Baltimore & Ohio R. R.															
Baltimore & Ohio Chicago Terminal R. R.	533,147	10 09	9.63	98.20									100.98	9.63	1.80
Calumet, Hammond & Southeastern R. R.															
Chesapeake & Ohio Ry. of Indiana															
Chicago & Alton R. R.	188,660	3.57	3.41	99.73									35.73	3.41	0.27
Chicago & Calumet River R. R.															
Chicago & Eastern Illinois R. R.	356,656	6.75	6.44	98.88									67.55	6.44	1.12
Chicago & Erie R. R.															
Chicago & Illinois Western R. R.	87,965	1.66	1.59	98.59									16.66	1.59	1.41
Chicago & North Western Ry.	603,193	11.42	10.88	83.55	114,932	66.81	2.09	15.92					136.01	12.97	0.53
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	59,650	1.13	1.08	71.02	21,000	12.21	0.38	25.00					15.27	1.46	3.98
Chicago, Burlington & Quincy R. R.	415,753	7.87	7.51	98.46									78.75	7.51	1.54
Chicago Great Western R. R.	81,483	1.54	1.47	99.09									15.43	1.47	0.91
Chicago, Indiana & Southern R. R.															
Chicago, Indianapolis & Louisville Ry.															
Chicago Junction Ry.															
Chicago, Milwaukee & St. Paul Ry.	529,581	10.02	9.56	94.49	22,420	13.03	0.40	4.00					104.55	9.96	1.51
Chicago River & Indiana R. R.															
Chicago, Rock Island & Pacific Ry.	319,060	6.04	5.76	98.39									60.43	5.76	1.61
Chicago Short Line Ry.															
Chicago Union Transfer Ry.	497,657	9.42	8.99	97.58									94.25	8.99	2.42
Chicago, West Pullman & Southern R. R.															
Elgin, Joliet & Eastern Ry.	40,435	0.77	0.73	100.00									7.66	0.73	0.00
Grand Trunk Western Ry.	173,102	3.28	3.13	98.54									32.78	3.13	1.46
Illinois Central R. R.	237,981	4.51	4.30	94.71	8,000	4.65	0.14	3.18					46.50	4.44	2.11
Illinois Northern Ry.															
Indiana Harbor Belt R. R.	527,100	9.98	9.52	98.40									99.83	9.52	1.60
Lake Shore & Michigan Southern Ry.															
Manufacturers' Junction Ry.	55,097	1.04	1.00	88.73	5,675	3.30	0.10	9.14					11.50	1.10	2.13
Michigan Central R. R.	76,078	1.44	1.37	97.56									14.41	1.37	2.43
Minneapolis, St. Paul & Sault Ste. Marie Ry.	165,565	3.13	2.99	98.74									31.36	2.99	1.26
New York, Chicago & St. Louis R. R.	24,434	0.46	0.44	98.07									4.62	0.44	1.93
Pere Marquette R. R.	45,513	0.86	0.82	100.00									8.63	0.82	0.00
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	100,032	1.89	1.81	99.23									18.95	1.81	0.77
Pittsburgh, Fort Wayne & Chicago Ry.															
Pullman Railroad															
South Chicago & Southern R. R.*	39,720	0.75	0.72	99.08									7.52	0.72	0.92
Wabash R. R.	47,721	0.90	0.86	97.62									9.04	0.86	2.38
Crossovers, all railroads													15 40	1 47	
Totals	5,283,668	100.00	95.42		172,027	100.00	3.11						1,048 68	100.00	

* Operated by the Pennsylvania Railroad.

TABLE CXLVII. MILEAGE OF STEAM RAILROAD TRACK. SUMMARY OF SURFACE AND ELEVATED TRACK, BY ROADS
ZONE B IN INDIANA
(Basis of 1912)

Railroad	Surface Track				Elevated Track				Miles	Per Cent of Total Track in Zone B-Ind.	Per Cent of Track in Crossovers
	Lineal Feet	Per Cent of Surface Track in Zone B-Ind.	Per Cent of Total Track in Zone B-Ind.	Per Cent of Co.'s Track in Zone B-Ind.	Lineal Feet	Per Cent of Elevated Track in Zone B-Ind.	Per Cent of Total Track in Zone B-Ind.	Per Cent of Co.'s Track in Zone B-Ind.			
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.											
Baltimore & Ohio R. R.	246,515	7.47	7.37	99.32					46.69	7.37	0.68
Baltimore & Ohio Chicago Terminal R. R.	168,777	5.11	5.04	98.56					31.97	5.04	1.44
Calumet, Hammond & Southeastern R. R.											
Chesapeake & Ohio Ry. of Indiana	34,825	1.05	1.04	100.00					6.60	1.04	0.00
Chicago & Alton R. R.											
Chicago & Calumet River R. R.											
Chicago & Eastern Illinois R. R.											
Chicago & Erie R. R.	157,728	4.78	4.71	99.07					29.87	4.71	0.93
Chicago & Illinois Western R. R.											
Chicago & North Western Ry.											
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago											
Chicago, Burlington & Quincy R. R.											
Chicago Great Western R. R.											
Chicago, Indiana & Southern R. R.	542,881	16.45	16.23	99.04					102.82	16.23	0.96
Chicago, Indianapolis & Louisville Ry.	128,891	3.90	3.85	99.46					24.41	3.85	0.54
Chicago Junction Ry.											
Chicago, Milwaukee & St. Paul Ry.											
Chicago River & Indiana R. R.											
Chicago, Rock Island & Pacific Ry.											
Chicago Short Line Ry.											
Chicago Union Transfer Ry.											
Chicago, West Pullman & Southern R. R.											
Elgin, Joliet & Eastern Ry.	950,176	28.79	28.40	97.92	6,700	100.00	0.20	0.69	181.23	28.60	1.39
Grand Trunk Western Ry.											
Illinois Central R. R.											
Illinois Northern Ry.											
Indiana Harbor Belt R. R.	152,719	4.63	4.56	99.87					28.92	4.56	0.13
Lake Shore & Michigan Southern Ry.	385,695	11.68	11.53	98 35					73.05	11.53	1.65
Manufacturers' Junction Ry.											
Michigan Central R. R.	98,055	2.97	2.93	99.38					18.57	2.93	0.62
Minneapolis, St. Paul & Sault Ste. Marie Ry.											
New York, Chicago & St. Louis R. R.	65,200	1.98	1.95	98.67					12.35	1.95	1.33
Pere Marquette R. R.											
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.											
Pittsburgh, Fort Wayne & Chicago Ry.	246,705	7.47	7.37	98.69					46.72	7.37	1.31
Pullman Railroad											
South Chicago & Southern R. R.*	102,085	3.09	3.05	98.34					19.33	3.05	1.66
Wabash Railroad	20,848	0.63	0.63	100.00					3.95	0.63	0.00
Crossovers, all railroads									7.24	1.14	
Totals	3,301,100	100.00	98.66		6,700	100.00	0 20	0.69	633 72	100 00	

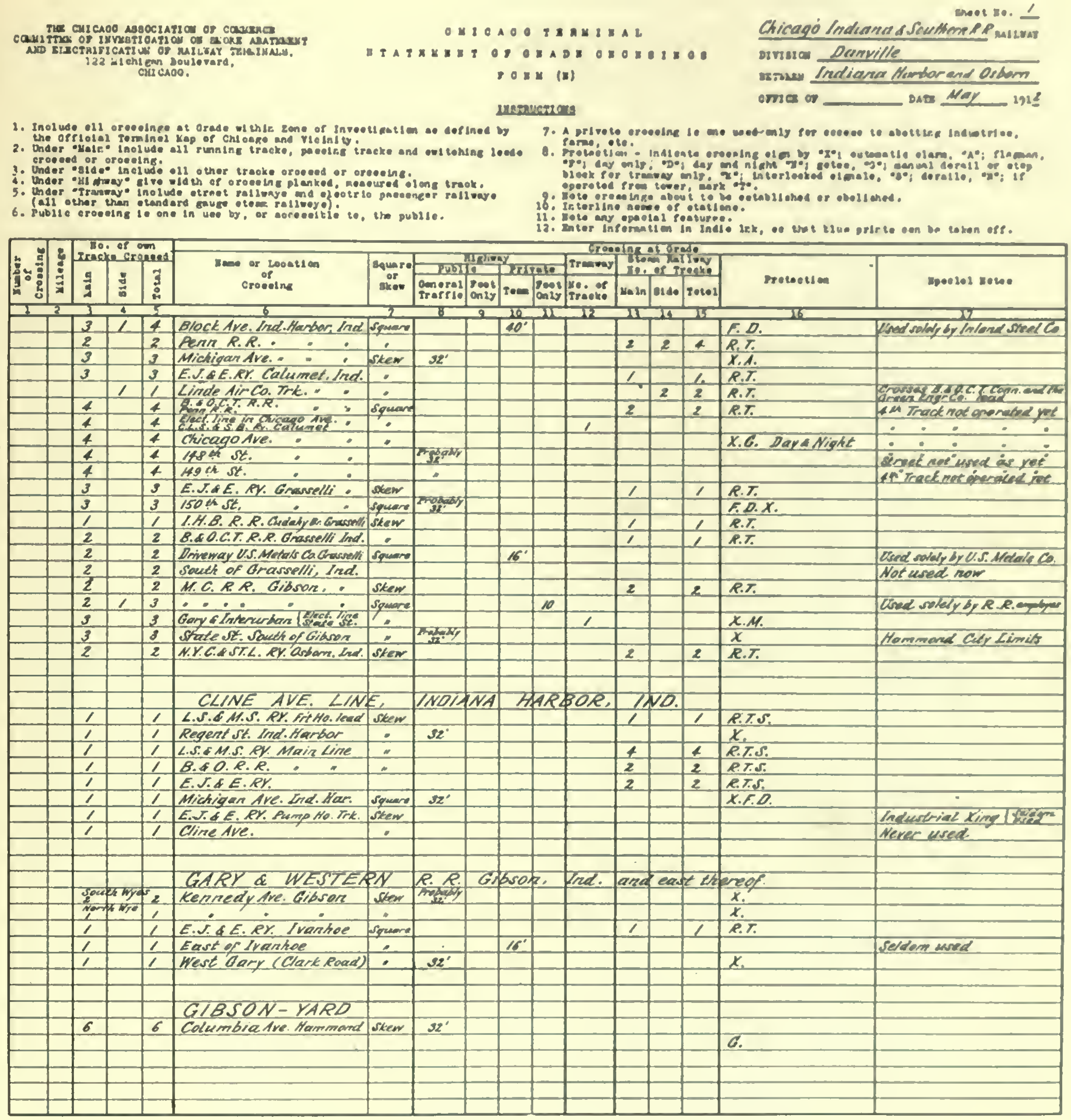
* Operated by the Pennsylvania R. R.

railroads cross each other at different levels. Due allowance has been made for such duplication, and the totals indicate the correct number of structures of each class.

From these summaries it will be seen that, within the Area of Investigation, steam railroad tracks are carried by bridges over 960 streets and highways, 874 of which are located within Zone A or the city of Chicago. Within the Area of Investigation there are 43 movable bridges over waterways, 30 of which are within the city of Chicago; 65 fixed bridges over waterways, 14 of which are within the city of Chicago; and 424 culverts, 151 of which are within the city of Chicago. All railroad bridges within the Area of Investigation embrace a total of 1,879 structures which are classed as railroad under crossing bridges, and 576 structures which are classed as railroad over crossing bridges. The net total of all such structures, after deducting 56 to allow for bridges reported and counted twice, amounts to 2,399. Bridges over streets and highways usually consist of plate girder spans with solid and waterproofed floors. Movable bridges over waterways are of the swing, rolling lift, bascule or lift types. Fixed bridges over waterways are of the truss or plate girder types.

Illustrations of a number of different types of bridges employed by the steam railroads of Chicago are presented as figs. 264 to 273, inclusive.

201.08 Track Elevation: As a result of activities extending over the past quarter of a century, most of the railroad lines entering the city are now elevated, together with a number of minor yards closely connected with the main lines. The effect of this elevation is to separate the



THE CHICAGO ASSOCIATION OF COMMERCE
COMMITTEE OF INVESTIGATION ON SMOKE ABATEMENT
AND ELECTRIFICATION OF RAILWAY TERMINALS.
122 Michigan Boulevard,
CHICAGO.

CHICAGO TERMINAL
STATEMENT OF GRADE CROSSINGS
FORM (E)

Sheet No. 1
Chicago Indiana & Southern R.R. RAILWAY
DIVISION Danville
BETWEEN Indiana Harbor and Osborn
OFFICE OF ______ DATE May 1918

INSTRUCTIONS

1. Include all crossings at Grade within Zone of Investigation as defined by the Official Terminal Map of Chicago and Vicinity.
2. Under "Main" include all running tracks, passing tracks and switching leads crossed or crossing.
3. Under "Side" include all other tracks crossed or crossing.
4. Under "Highway" give width of crossing planked, measured along track.
5. Under "Tramway" include street railways and electric passenger railways (all other than standard gauge steam railways).
6. Public crossing is one in use by, or accessible to, the public.
7. A private crossing is one used only for access to abutting industries, farms, etc.
8. Protection - indicate crossing sign by "X"; automatic alarm, "A"; flagman, "F"; day only, "D"; day and night "N"; gates, "G"; manual derail or stop block for tramway only, "M"; interlocked signals, "S"; derails, "R"; if operated from tower, mark "T".
9. Note crossings about to be established or abolished.
10. Interline names of stations.
11. Note any special features.
12. Enter information in Indian Ink, so that blue prints can be taken off.

Number of Crossing	Mileage	No. of own Tracks Crossed			Crossing at Grade											
					Name or Location of Crossing	Square or Skew	Highway				Tramway	Steam Railway No. of Tracks			Protection	Special Notes
							Public		Private							
		Main	Side	Total			General Traffic	Foot Only	Team	Foot Only	No. of Tracks	Main	Side	Total		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		3	1	4	Block Ave. Ind. Harbor, Ind.	Square			40'						F. D.	Used solely by Inland Steel Co
		2		2	Penn R.R. " " "	"						2	2	4	R.T.	
		3		3	Michigan Ave. " " "	Skew	32'								X.A.	
		3		3	E.J.&E.RY. Calumet, Ind.	"						1		1	R.T.	
			1	1	Linde Air Co. Trk. " "	"							2	2	R.T.	Crosses B.&O.C.T. Conn. and the Green Engr. Co. lead
		4		4	B.&O.C.T. R.R. Penn R.R. " "	Square						2		2	R.T.	4th Track not operated yet
		4		4	Elect. line in Chicago Ave. C.L.S.&S.B. Ry. Calumet "	"					1					" " " " "
		4		4	Chicago Ave. " "	"									X.G. Day & Night	" " " " "
		4		4	148th St. " "		Probably 32'									Street not used as yet
		4		4	149th St. " "		"									4th Track not operated yet
		3		3	E.J.&E. RY. Grasselli "	Skew						1		1	R.T.	
		3		3	150th St. " "	Square	Probably 32'								F.D.X.	
		1		1	I.H.B. R.R. Cudahy Br. Grasselli	Skew						1		1	R.T.	
		2		2	B.&O.C.T. R.R. Grasselli Ind.	"						1		1	R.T.	
		2		2	Driveway U.S. Metals Co. Grasselli	Square			16'							Used solely by U.S. Metals Co.
		2		2	South of Grasselli, Ind.											Not used now
		2		2	M.C. R.R. Gibson, "	Skew						2		2	R.T.	
		2	1	3	" " " " " "	Square				10						Used solely by R.R. employes
		3		3	Gary & Interurban {Elect. line State St.}	"					1				X.M.	
		3		3	State St. South of Gibson	"	Probably 32'								X	Hammond City Limits
		2		2	N.Y.C.& ST.L. RY. Osborn, Ind.	Skew						2		2	R.T.	
					CLINE AVE. LINE, INDIANA HARBOR, IND.											
		1		1	L.S.&M.S. RY. Frt Ho. lead	Skew						1		1	R.T.S.	
		1		1	Regent St. Ind. Harbor	"	32'								X.	
		1		1	L.S.&M.S. RY. Main Line	"						4		4	R.T.S.	
		1		1	B.&O. R.R. " "	"						2		2	R.T.S.	
		1		1	E.J.&E. RY.							2		2	R.T.S.	
		1		1	Michigan Ave. Ind. Har.	Square	32'								X.F.D.	
		1		1	E.J.&E. RY. Pump Ho. Trk.	Skew										Industrial Xing {Seldom used}
		1		1	Cline Ave.	"										Never used
					GARY & WESTERN R. R. Gibson, Ind. and east thereof.											
		South Wyes 2		2	Kennedy Ave. Gibson	Skew	Probably 32'								X.	
		North Wye 1		1	" " "	"									X.	
		1		1	E.J.&E. RY. Ivanhoe	Square						1		1	R.T.	
		1		1	East of Ivanhoe	"			16'							Seldom used
		1		1	West Gary (Clark Road)	"	32'								X.	
					GIBSON - YARD											
		6		6	Columbia Ave. Hammond	Skew	32'									
															G.	

FIG. 247. "FORM E." STATEMENT OF GRADE CROSSINGS OF A STEAM RAILROAD, CHICAGO TERMINALS

TABLE CXLVIII. SUMMARY OF STEAM RAILROAD GRADE CROSSINGS. ZONES A AND B
(Basis of 1912)

Railroad	Steam Railroad Crossings				Electric Railway Crossings				Public Street and Highway Crossings				Public Footway Crossings				Private Teamway Crossings				Private Footway Crossings				Totals				
	Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.						
Zone	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	Zone A	Zone B	Surf.	Elev.	All
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Atchison, Topeka & Santa Fe Ry.	8	1	1		1	1			8	3															18	5	22	1	23
Baltimore & Ohio R. R.	5	6	3		6		1		26	7	1							4							42	17	54	5	59
Baltimore & Ohio Chicago Terminal R. R.	9	36	11		5	17			33	136	1			4				31							59	224	271	12	283
Calumet, Hammond & Southeastern R. R.																	7								7		7		7
Chesapeake & Ohio Ry. of Indiana										4								5								9	9		9
Chicago & Alton R. R.	3	1	3		1				9	1							1								17	2	16	3	19
Chicago & Calumet River R. R.																													None
Chicago & Eastern Illinois R. R.		1								3																4	4		4
Chicago & Erie R. R.		2				4				15																21	21		21
Chicago & Illinois Western R. R.		4				2				4																10	10		10
Chicago & North Western Ry.	4		7		6				87	29		1		3			12	14	6	2					122	49	155	16	171
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	21	6	2		13				63	3							11				1				111	9	118	2	120
Chicago, Burlington & Quincy R. R.	6				25	2			39	16							9					4			79	22	101		101
Chicago Great Western R. R.		1				1				22								1								25	25		25
Chicago, Indiana & Southern R. R.		13				2				12								3				1				31	31		31
Chicago, Indianapolis & Louisville Ry.		4				4				15																23	23		23
Chicago Junction Ry.			6		4				70								49								129		123	6	129
Chicago, Milwaukee & St. Paul Ry.	1	1	6		28				169	22			4				2				2				212	23	229	6	235
Chicago River & Indiana R. R.					1				4								6								11		11		11
Chicago, Rock Island & Pacific Ry	14		5		8		1		68	9	1						2	1							99	10	102	7	109
Chicago Short Line Ry.	1				1				2																4		4		4
Chicago Union Transfer Ry.	2				1				7	1															10	1	11		11
Chicago, West Pullman & Southern R. R.	3				5				9																17		17		17
Elgin, Joliet & Eastern Ry.	1	16			1	6			6	24							1	1							9	47	56		56
Grand Trunk Western Ry.	2	4			2	1			18	32															22	37	59		59
Illinois Central R. R.	10	5	7		7	6			59	49			1				1	8			1				86	68	147	7	154
Illinois Northern Ry.	3		4		1				11								5								24		20	4	24
Indiana Harbor Belt R. R.	3	27			2	10			8	66								36							13	139	152		152
Lake Shore & Michigan Southern Ry.		3	2						1	7							1	4							4	14	16	2	18
Manufacturers' Junction Ry.		1				1				1								16								19	19		19
Michigan Central R. R.		9				2			6	16							4	3							10	30	40		40
Minneapolis, St. Paul & Sault Ste. Marie Ry.		1				1				16								12								30	30		30
New York, Chicago & St. Louis R. R.	3	10			1	3			8	18							1	1							13	32	45		45
Pere Marquette R. R.																													
Pittsburgh, Cincinnati, Chicago & St. Louis Ry. Pittsburgh, Fort Wayne & Chicago Ry.	23	19	8		14	7			113	65				1			6	16							164	108	264	8	272
Pullman Railroad																													None
Wabash Railroad	3	1			1				9	9			1	1				4							14	15	29		29
	125	172	65	0	134	70	2	0	833	605	3	1	6	9	0	0	118	160	6	2	4	5	0	0	1,296	1,024			
Totals	297 Net 165		65 Net 34		204		2		1,438		4		15		0		278		8		9		0		Surf 1,220 Elev 76	Surf 1,021 Elev. 3	2,241	79	2,320*
	*362—Net 199				206				1,442				15				286				9				Net Total 2,157				

*Deduct 163 steam railroad crossings counted twice for net total.

TABLE CXLIX. SUMMARY OF STEAM RAILROAD GRADE CROSSINGS OF STEAM RAILROADS, SHOWING FORM OF PROTECTION. ZONES A AND B
(Basis of 1912)

Railroad	Interlocking				Gates				Flagman				Crossing Sign				Other Protection				No Protection				Totals				All
	Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		
Zone	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Atchison, Topeka & Santa Fe Ry.	4	1							4		1														8	1	1		10
Baltimore & Ohio R. R.	3	6			1						3		1												5	6	3		14
Baltimore & Ohio Chicago Terminal R. R.	6	29							3	1	5			1					6			5			9	36	11		56
Calumet, Hammond & Southeastern R. R.																													
Chesapeake & Ohio Ry. of Indiana																													
Chicago & Alton R. R.	1	1	3																		2				3	1	3		7
Chicago & Calumet River R. R.																													
Chicago & Eastern Illinois R. R.		1																								1			1
Chicago & Erie R. R.		2																								2			2
Chicago & Illinois Western R. R.		2												1								1				4			4
Chicago & North Western Ry.	3		5						1		2														4		7		11
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	13	6	2		5				1												2				21	6	2		29
Chicago, Burlington & Quincy R. R.									6																6				6
Chicago Great Western R. R.		1																								1			1
Chicago, Indiana & Southern R. R.		13																								13			13
Chicago, Indianapolis & Louisville Ry.		3																				1				4			4
Chicago Junction Ry.			1								4												1				6		6
Chicago, Milwaukee & St. Paul Ry.	1	1	6																						1	1	6		8
Chicago River & Indiana R. R.																													
Chicago, Rock Island & Pacific Ry.	6		3		1				2		2										5				14		5		19
Chicago Short Line Ry.	1																								1				1
Chicago Union Transfer Ry.	2																								2				2
Chicago, West Pullman & Southern R. R.																					3				3				3
Elgin, Joliet & Eastern Ry.	1	8				1				2				5											1	16			17
Grand Trunk Western Ry.		3			2	1																			2	4			6
Illinois Central R. R.	7	5	7						2												1				10	5	7		22
Illinois Northern Ry.	3										4														3		4		7
Indiana Harbor Belt R. R.	3	20																				7			3	27			30
Lake Shore & Michigan Southern Ry.		3	2																							3	2		5
Manufacturers' Junction Ry.		1																								1			1
Michigan Central R. R.		9																								9			9
Minneapolis, St. Paul & Sault Ste. Marie Ry.		1																								1			1
New York, Chicago & St. Louis R. R.		10			3																				3	10			13
Pere Marquette R. R.																													
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	12	18	2						5		5										6	1	1		23	19	8		50
Pittsburgh, Fort Wayne & Chicago Ry.																													
Pullman Railroad																													
Wabash Railroad	2	1			1																				3	1			4
Totals Zone A: Surface	68				13				24				1				0				19				125				190
Elevated			31				0				26				0				6				2				65		
Totals Zone B: Surface		145				2				3				7				0				15				172			172
Elevated				0				0				0				0				0				0				0	
Grand totals	244				15				53				8				6				36				Grand total				363
Deduct duplications	122				7				26				4				3				1				Deduct duplications				163
Net totals	122				8				27				4				3				35 = 17.6%				Net total				199

Total protected = 164 = 82.4%
Total not protected = 35 = 17.6%

TABLE CL SUMMARY OF STEAM RAILROAD GRADE CROSSINGS OF ELECTRIC RAILWAYS, SHOWING FORM OF PROTECTION. ZONES A AND B

(Basis of 1912)

Railroad	Interlocking				Gates				Flagman				Automatic Bell				Crossing Sign				Other Protection				No Protection				Totals				All
	Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		
Zone	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A		A	B	A	B	A	B	A	B	A	B	A	B	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Atchison, Topeka & Santa Fe Ry.					1													1											1	1			2
Baltimore & Ohio R. R.					3												2		1		1								6		1		7
Baltimore & Ohio Chicago Terminal R. R.		1			5	4				2								3				1				6			5	17			22
Calumet, Hammond & Southeastern R. R.																																	
Chesapeake & Ohio Ry. of Indiana																																	
Chicago & Alton R. R.																									1				1				1
Chicago & Calumet River R. R.																																	
Chicago & Eastern Illinois R. R.																																	
Chicago & Erie R. R.						3				1																				4			4
Chicago & Illinois Western R. R.																		2												2			2
Chicago & North Western Ry.					2																				4				6				6
Chicago & Western Indiana R. R. and the Belt Railway of Chicago					8				3																22				13				13
Chicago, Burlington & Quincy R. R.					3					1															2	1			25	2			27
Chicago Great Western R. R.						1																								1			1
Chicago, Indiana & Southern R. R.						1																1								2			2
Chicago, Indianapolis & Louisville Ry.						3				1																				4			4
Chicago Junction Ry.									2																2				4				4
Chicago, Milwaukee & St. Paul Ry.	10				9				7																2				28				28
Chicago River & Indiana R. R.					1																								1				1
Chicago, Rock Island & Pacific Ry.	2				4						1														2				8		1		9
Chicago Short Line Ry.																									1				1				1
Chicago Union Transfer Ry.					1																								1				1
Chicago, West Pullman & Southern R. R.					1																				4				5				5
Elgin, Joliet & Eastern Ry.		2			1	1				3																			1	6			7
Grand Trunk Western Ry.					2					1																			2	1			3
Illinois Central R. R.					3				2	2			1	1			1									3			7	6			13
Illinois Northern Ry.													1																1				1
Indiana Harbor Belt R. R.		2								3			2	3												2			2	10			12
Lake Shore & Michigan Southern Ry.																																	
Manufacturers' Junction Ry.																										1				1			1
Michigan Central R. R.		1				1																								2			2
Minneapolis, St. Paul & Sault Ste. Marie Ry.						1																								1			1
New York, Chicago & St. Louis R. R.						3																			1				1	3			4
Pere Marquette R. R.																																	
Pittsburgh, Cincinnati, Chicago & St. Louis Ry. Pittsburgh, Fort Wayne & Chicago Ry.	1				8	1			4									1				1			1	4			14	7			21
Pullman Railroad																																	
Wabash Railroad					1																								1				1
Totals Zone A: Surface	13				53				18				4				3				1				42				134				136
Elevated			0				0				1				0				1				0				0				2		
Totals Zone B: Surface		6				19				14				4				7				3				17				70			70
Elevated				0				0				0				0				0				0				0				0	
Grand totals	19				72				33				8				11				4				59 = 28.7%				206				206

Total protected = 147 = 71.3%
Total not protected = 59 = 28.7%

TABLE CLI. SUMMARY OF STEAM RAILROAD GRADE CROSSINGS OF STREETS AND HIGHWAYS, SHOWING FORM OF PROTECTION. ZONES A AND B
(Basis of 1912)

Railroad	Gates				Flagman				Auto. Bell				Crossing Sign				Other Protection				No Protection				Totals				
	Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		All
Zone	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Atchison, Topeka & Santa Fe Ry.	1				3	3															4				8	3			11
Baltimore & Ohio R. R.	4	2			1	1							16	1	1						5	3			26	7	1		34
Baltimore & Ohio Chicago Terminal R. R.	9	16	1		6	18				1			16	69				4			2	28			33	136	1		170
Calumet, Hammond & Southeastern R. R.																													
Chesapeake & Ohio Ry. of Indiana						1								3												4			4
Chicago & Alton R. R.																					9	1			9	1			10
Chicago & Calumet River R. R.																													
Chicago & Eastern Illinois R. R.						3																				3			3
Chicago & Erie R. R.		8				2								4								1				15			15
Chicago & Illinois Western R. R.																						4				4			4
Chicago & North Western Ry.	25	15			15	3			1				10	7							36	4		1	87	29		1	117
Chicago & Western Indiana R. R. and the Belt Railway of Chicago	22	3			23								1								17				63	3			66
Chicago, Burlington & Quincy R. R.	19	9			6	1				1											14	5			39	16			55
Chicago Great Western R. R.		2				1																19				22			22
Chicago, Indiana & Southern R. R.		2				2				1				5								2				12			12
Chicago, Indianapolis & Louisville Ry.		9				1																5				15			15
Chicago Junction Ry.	1				26				1				4								38				70				70
Chicago, Milwaukee & St. Paul Ry.	73				58	3				1											38	18			169	22			191
Chicago River & Indiana R. R.	1				1																2				4				4
Chicago, Rock Island & Pacific Ry.	24	3			7	2	1														37	4			68	9	1		78
Chicago Short Line Ry.																					2				2				2
Chicago Union Transfer Ry.	1												3	1							3				7	1			8
Chicago, West Pullman & Southern R. R.	1																				8				9				9
Elgin, Joliet & Eastern Ry.	3	3				6							3	15											6	24			30
Grand Trunk Western Ry.	4	8			1	4							12	20							1				18	32			50
Illinois Central R. R.	10	3			10	5			1	8			33	25							5	8			59	49			108
Illinois Northern Ry.					1				1				7								2				11				11
Indiana Harbor Belt R. R.		1				6							8	59											8	66			74
Lake Shore & Michigan Southern Ry.		2			1	3								2											1	7			8
Manufacturers' Junction Ry.																						1				1			1
Michigan Central R. R.	2	6			1	1				1			2	8							1				6	16			22
Minneapolis, St. Paul & Sault Ste. Marie Ry.		2								5												9				16			16
New York, Chicago & St. Louis R. R.	1	10											6	7							1	1			8	18			26
Pere Marquette R. R.																													
Pittsburgh, Cincinnati, Chicago & St. Louis Ry. Pittsburgh, Fort Wayne & Chicago Ry.	31	10			30	4			9	1			1	28							42	22			113	63			178
Pullman Railroad																													
Wabash Railroad	3				1								5	8								1			9	9			18
Totals Zone A: Surface	235				191				13				127								267				833				836
Elevated			1				1				0				1				0				0				3		
Totals Zone B: Surface		114				70				19				262				4				136				605			606
Elevated				0				0				0				0				0				1				1	
Grand totals		350				262					32			390				4				404 = 28%			1,438		4		1,442

Total protected = 1038 = 72%
Total not protected = 404 = 28%

TABLE CLII. SUMMARY OF STEAM RAILROAD GRADE CROSSINGS OF FOOTWAYS AND TEAMWAYS, SHOWING FORM OF PROTECTION. ZONES A AND B

(Basis of 1912)

Railroad	Public Footways			Private Teamways																									Private Footways		
	No Protection			Gates				Flagman				Crossing Sign				Other Protection				No Protection				Totals				All	No Protection		
	Surf.		Total	Surf.		Elev.		Surf.		Elev.		Surf.		Elev		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.			Surf.		Total
Zone	A	B		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B		A	B	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Atchison, Topeka & Santa Fe Ry.																															
Baltimore & Ohio R. R.																					4				4			4			
Baltimore & Ohio Chicago Terminal R. R.		4	4		20								1								10				31			31			
Calumet, Hammond & Southeastern R. R.												1								6				7				7			
Chesapeake & Ohio Ry. of Indiana																					5				5			5			
Chicago & Alton R. R.																				1				1				1			
Chicago & Calumet River R. R.																															
Chicago & Eastern Illinois R. R.																															
Chicago & Erie R. R.																															
Chicago & Illinois Western R. R.																															
Chicago & North Western Ry.		3	3					1												11	14	6	2	12	14	6	2	34			
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago								1												10				11				11	1		1
Chicago, Burlington & Quincy R. R.																				9				9				9		4	4
Chicago Great Western R. R.																					1				1			1			
Chicago, Indiana & Southern R. R.																					3				3			3		1	1
Chicago, Indianapolis & Louisville Ry.																															
Chicago Junction Ry.																				49				49				49			
Chicago, Milwaukee & St. Paul Ry.	4		4																	2				2				2	2		2
Chicago River & Indiana R. R.																				6				6				6			
Chicago, Rock Island & Pacific Ry.																				2	1			2	1			3			
Chicago Short Line Ry.																															
Chicago Union Transfer Ry.																															
Chicago, West Pullman & Southern R. R.																															
Elgin, Joliet & Eastern Ry.													1							1				1	1			2			
Grand Trunk Western Ry.																															
Illinois Central R. R.	1		1									1	4								4			1	8			9	1		1
Illinois Northern Ry.								2				1								2				5				5			
Indiana Harbor Belt R. R.													34								2				36			36			
Lake Shore & Michigan Southern Ry.																				1	4			1	4			5			
Manufacturers' Junction Ry.																					16				16			16			
Michigan Central R. R.																				4	3			4	3			7			
Minneapolis, St. Paul & Sault Ste. Marie Ry.																					12				12			12			
New York, Chicago & St. Louis R. R.																				1	1			1	1			2			
Pere Marquette R. R.																															
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.																															
Pittsburgh, Fort Wayne & Chicago Ry.		1	1																	6	16			6	16			22			
Pullman Railroad																															
Wabash Railroad	1	1	2										2								2				4			4			
Totals Zone A: Surface	6			0				4				3								111				118					4		
Totals Zone A: Elevated						0								0								6				6					
Totals Zone B: Surface		9			20				0				42								98				160					5	
Totals Zone B: Elevated											0				0								2				2				
Grand totals	15			20				4				45								217 = 76%				286				286			9

Total protected = 69 = 24%

Total not protected = 217 = 76%

TABLE CLIII. SUMMARY OF ALL CROSSINGS OF STEAM RAILROAD TRACKS. ZONES A AND B
(Basis of 1912)

Crossings of Steam Railroad Tracks by	Zone A			Zone B			Zones A and B			
	Grade	Grades Separated		Grade	Grades Separated		Grade	Grades Separated		Total
		Over	Under		Over	Under		Over	Under	
1	2	3	4	5	6	7	8	9	10	11
Steam railroads	190	38	37	172	18	20	362	56	57	475
Electric railroads	136	95	261	70	4	14	206	99	275	580
Street and highways	836	59	876	605	12	84	1,441	71	960	2,472
Public footways	6	25	13	9	..	2	15	25	15	55
Private teamways	124	...	9	162	..	3	286	...	12	298
" footways	4	3	..	5	1	1	9	4	1	14
Miscellaneous	....	115	15	....	..	12	....	115	27	142
Waterways—movable	....	...	30	....	..	13	....	...	43	43
" fixed	....	...	14	....	..	51	....	...	65	65
" culverts	....	...	151	....	..	273	....	...	424	424
Signal bridges	....	155	....	....	51	...	....	206	....	206
Totals	1,296	490	1,406	1,023	86	473	2,319	576	1,879	4,774
Deduct for steam railroad crossings counted twice										219
Net total number of crossings of all classes										4,555

trackage of the railroads from the surface of city streets. This has been accomplished in most cases by raising the grade of the railroad and by lowering that of the intersecting street. Bridges of various types, upon which the road-bed is carried over the streets, have been employed. The road-bed between cross streets is maintained usually on embankments between the retaining walls set along the edges of the right-of-way.

A map showing the extent and location of the elevated steam railroad lines in the Area of Investigation is presented as fig. 274.

A statistical record of the number of miles of elevated steam railroad road-bed and track completed or under construction, December 31, 1914, and of the additional number of miles required by ordinances to be elevated is presented by roads as table CLVI.

Types of viaducts and retaining walls used in connection with the elevation of steam railroad lines in the city of Chicago are illustrated by figs. 275 to 280, inclusive.

201.09 Signal Systems: All steam railroads operating in the Chicago District were requested to furnish complete information concerning their block signal systems, signal bridges and interlocking towers within the city of Chicago. For this purpose the Committee supplied each railroad with copies of "Form H," "Statement of Signals," a reproduction of which is presented as fig. 281.

A summary of the information thus furnished by the railroad companies, concerning block signals, signal bridges and interlocking plants within the city of Chicago, is presented as table CLVII.

Reference to table CLVII shows that within the city limits of Chicago there are 160 signal bridges, 88 interlocking plants, 86 interlocking towers and 879 signals operated by track circuits. The 88 interlocking plants control 2,784 switches and 2,075 signals. In the entire Area of Investigation there are 131 interlocking plants and 128 interlocking towers, controlling 3,903 switches and 3,276 signals.

Nearly all of the existing automatic block signals are operated by direct current track circuits, although a few using alternating current circuits have been installed. Within the proposed limits of electrification there is the equivalent of 800 miles of single main track protected by automatic signals.

Automatic signals used in the Chicago terminals are of a number of types, varying with the designs of the different manufacturers of such apparatus. Both upper and lower quadrant semaphore signals find favor with the railroad companies. Since most of the railroads in Chicago have at least two main tracks, and frequently more, most of the automatic signals are carried on bridges which span the tracks and are constructed especially for that purpose. Excellent examples of modern signal bridges may be found on the lines of the Chicago & North Western Railway, the Lake Shore & Michigan Southern Railway and the Pittsburgh, Fort Wayne & Chicago Railway. These bridges occur at frequent intervals along the tracks and are of steel construction. A lighter form of bridge, for use with a different type of signal, may be seen upon the lines

FIG. 248. LOCATIONS OF ALL CROSSINGS OF STEAM RAILROAD TRACKS AT GRADE WITHIN AREA OF INVESTIGATION

FIG. 249. GRADE CROSSINGS. Highway and electric railway crossing of the Elgin, Joliet & Eastern Railway at 86th Street and Burley Avenue.

FIG. 250. GRADE CROSSINGS. Chicago & Interurban Railroad crossing of the Chicago, Rock Island & Pacific Railway at 90th Street and Vincennes Road.

FIG. 251. GRADE CROSSINGS. Crossing of the Chicago, Lake Shore & South Bend Railway (South Shore Lines), and spur from the Hammond Branch of the Pittsburgh, Fort Wayne & Chicago Railway, south of Hammond Station.

FIG. 252. GRADE CROSSINGS. Crossing of the Metropolitan "L" and the Baltimore & Ohio Chicago Terminal Railroad at Forest Park, Ill.

FIG. 253. GRADE CROSSINGS. Unprotected highway crossing of the Chicago & Council Bluffs Division of the Chicago, Milwaukee & St. Paul Railway, at Grand Avenue road, west of the Chicago city limits.

FIG. 254. GRADE CROSSINGS. Hammond, Ind., crossings of the Michigan Central Railroad, the Chicago & Erie Railroad and the New York, Chicago & St. Louis Railroad.

FIG. 255. GRADE CROSSINGS. Stony Island Avenue highway crossing of the South Chicago Branch of the Illinois Central Railroad.

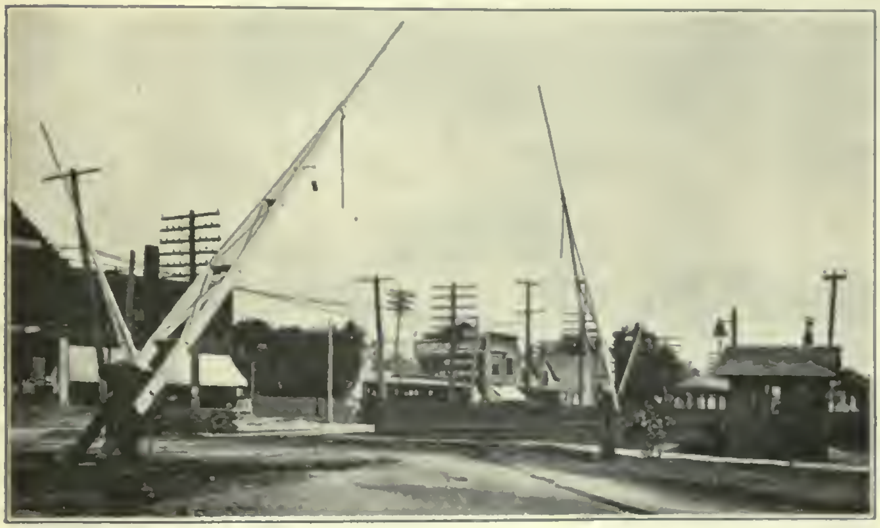


FIG. 256. GRADE CROSSINGS. Highway crossing of the Chicago, Burlington & Quincy Railroad at La Grange, Ill.

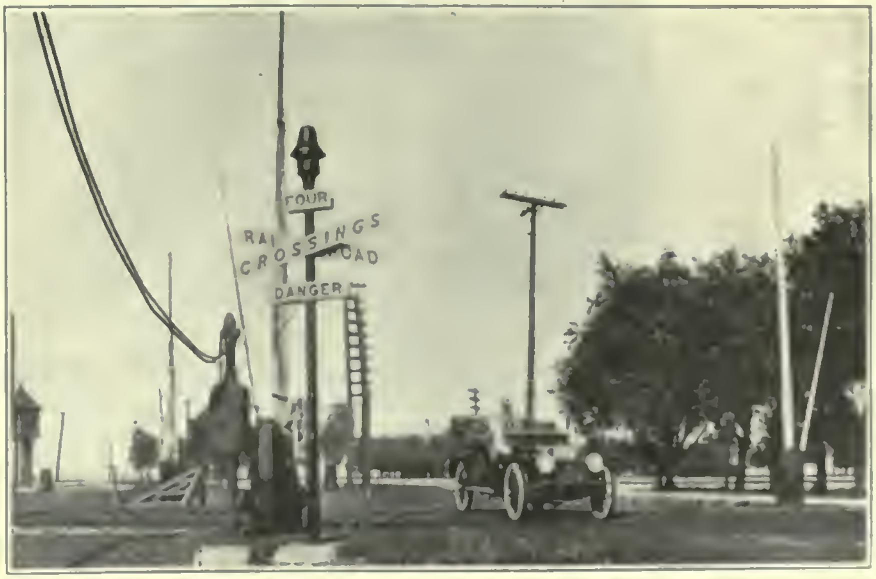


FIG. 257. GRADE CROSSINGS. Highway crossing of the Pittsburgh, Fort Wayne & Chicago Railway at Sheffield Avenue, one mile east of Illinois-Indiana State Line.

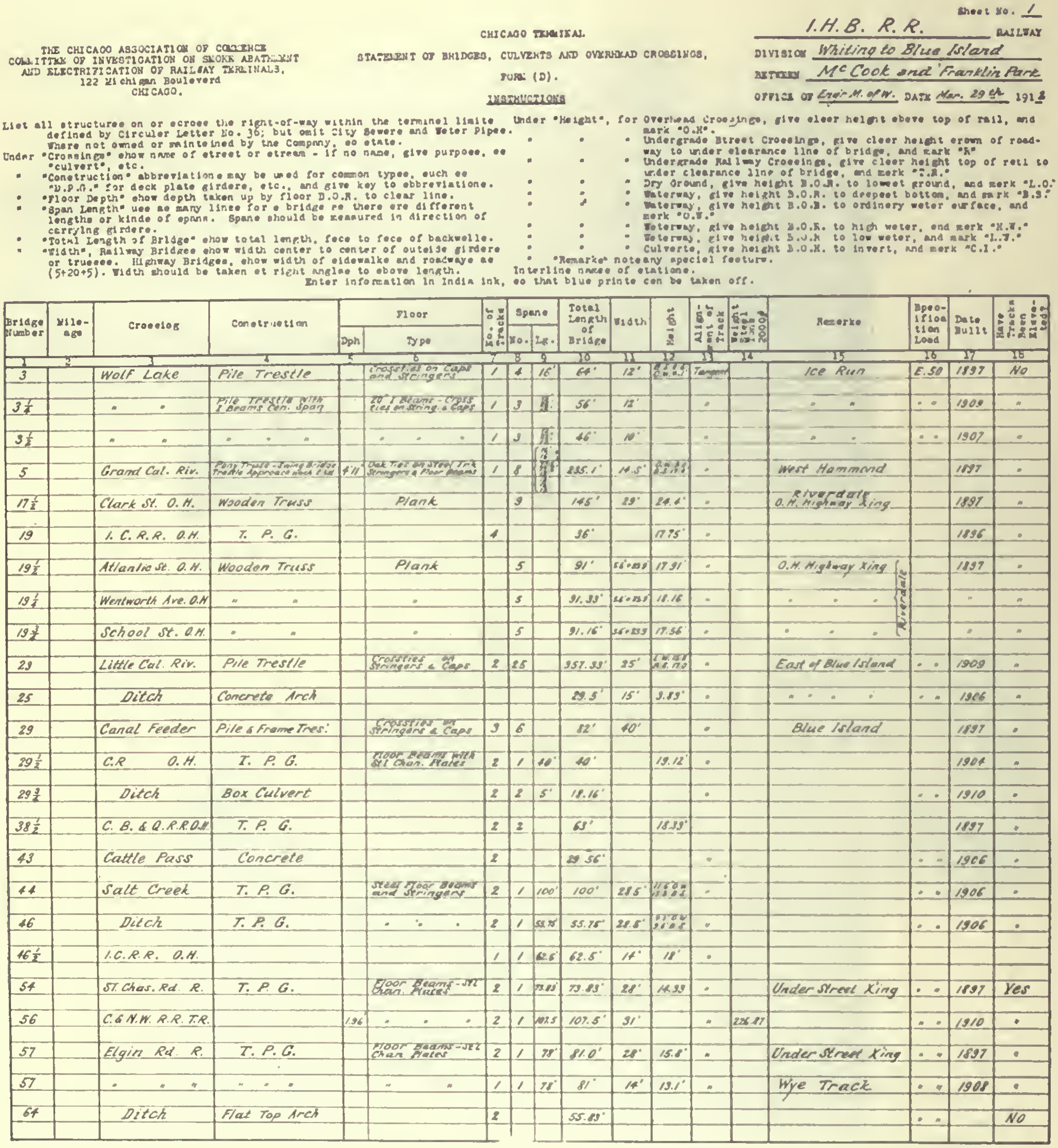
FIG. 258. GRADE CROSSINGS. Electric street railway crossing of the Chicago & Western Indiana Railroad, at Michigan Avenue in Kensington.

FIG. 259. GRADE CROSSINGS. Crossing of the Illinois Central Railroad with the Pittsburgh, Cincinnati, Chicago & St. Louis Railway and the Baltimore & Ohio Chicago Terminal Railroad, near Riverdale.

FIG. 260. GRADE CROSSINGS. Burnside crossing of the Illinois Central Railroad with the Belt Railway of Chicago and the Chicago, Rock Island & Pacific Railway.

FIG. 261. GRADE CROSSINGS. Washington Heights crossing of the Pittsburgh, Cincinnati, Chicago & St. Louis Railway with the Chicago, Rock Island & Pacific Railway.

FIG. 262. GRADE CROSSINGS. Crossing of the Chicago & North Western Railway and the Chicago, Milwaukee & St. Paul Railway, at Western Avenue.



Sheet No. 1

THE CHICAGO ASSOCIATION OF COMMERCE
COMMITTEE OF INVESTIGATION ON SMOKE ABATEMENT
AND ELECTRIFICATION OF RAILWAY TERMINALS.
122 Michigan Boulevard
CHICAGO.

CHICAGO TERMINAL

STATEMENT OF BRIDGES, CULVERTS AND OVERHEAD CROSSINGS,

FORM (D).

I.H.B. R.R. RAILWAY
DIVISION Whiting to Blue Island
BETWEEN Mc Cook and Franklin Park
OFFICE OF Engr. M. of W. DATE Mar. 29th 1912

INSTRUCTIONS

List all structures on or across the right-of-way within the terminal limits defined by Circular Letter No. 36; but omit City Sewers and Water Pipes. Where not owned or maintained by the Company, so state.

Under "Crossings" show name of street or stream - if no name, give purpose, as "culvert", etc.

" "Construction" abbreviations may be used for common types, such as "D.P.G." for deck plate girders, etc., and give key to abbreviations.

" "Floor Depth" show depth taken up by floor B.O.R. to clear line.

" "Span Length" use as many lines for a bridge as there are different lengths or kinds of spans. Spans should be measured in direction of carrying girders.

" "Total Length of Bridge" show total length, face to face of backwalls.

" "Width", Railway Bridges show width center to center of outside girders or trusses. Highway Bridges, show width of sidewalks and roadways as (5+20+5). Width should be taken at right angles to above length.

Under "Height", for Overhead Crossings, give clear height above top of rail, and mark "O.H".

" " " Undergrade Street Crossings, give clear height crown of roadway to under clearance line of bridge, and mark "R"

" " " Undergrade Railway Crossings, give clear height top of rail to under clearance line of bridge, and mark "T.R."

" " " Dry Ground, give height B.O.R. to lowest ground, and mark "L.G."

" " " Waterway, give height B.O.R. to deepest bottom, and mark "B.S."

" " " Waterway, give height B.O.R. to ordinary water surface, and mark "O.W."

" " " Waterway, give height B.O.R. to high water, and mark "H.W."

" " " Waterway, give height B.O.R. to low water, and mark "L.W."

" " " Culverts, give height B.O.R. to invert, and mark "C.I."

" "Remarks" note any special feature.

Interline names of stations.

Enter information in India ink, so that blue prints can be taken off.

Bridge Number	Mileage	Crossing	Construction	Floor		No. of Tracks	Spans		Total Length of Bridge	Width	Height	Alignment of Track	Weight Steel [illegible] 2000#	Remarks	Specification Load	Date Built	Have Tracks Been Elevated
				Dph	Type		No.	Lg.									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
3		Wolf Lake	Pile Trestle		Crossties on Caps and Stringers	1	4	16'	64'	12'	[illegible]	Tangent		Ice Run	E.50	1897	No
3¼		″ ″	Pile Trestle with I Beams Cen. Span		20" I Beams - Cross ties on String. & Caps	1	3	[illegible]	56'	12'		″		″ ″	″ ″	1909	″
3½		″ ″	″ ″ ″		″ ″ ″	1	3	[illegible]	46'	10'		″		″ ″	″ ″	1907	″
5		Grand Cal. Riv.	Pony Truss - Swing Bridge Trestle Approach each End	4'11"	Oak Ties on Steel Trk Stringers & Floor Beams	1	8	[illegible]	235.1'	14.5'	[illegible]	″		West Hammond		1897	″
17½		Clark St. O.H.	Wooden Truss		Plank		9		145'	29'	24.4'	″		Riverdale O.H. Highway Xing		1897	″
19		I. C. R.R. O.H.	T. P. G.			4			36'		17.75'	″				1896	″
19½		Atlantic St. O.H.	Wooden Truss		Plank		5		91'	56+23.9	17.91'	″		O.H. Highway Xing Riverdale		1897	″
19¼		Wentworth Ave. O.H	″ ″		″		5		91.33'	56+23.9	18.16	″		″ ″ ″		″	″
19¾		School St. O.H.	″ ″		″		5		91.16'	56+23.9	17.56'	″		″ ″ ″		″	″
23		Little Cal. Riv.	Pile Trestle		Crossties on Stringers & Caps	2	25		357.33'	25'	[illegible]	″		East of Blue Island	″ ″	1909	″
25		Ditch	Concrete Arch						29.5'	15'	3.83'	″		″ ″ ″ ″	″ ″	1906	″
29		Canal Feeder	Pile & Frame Tres.		Crossties on Stringers & Caps	3	6		82'	40'		″		Blue Island		1897	″
29½		C.R O.H.	T. P. G.		Floor Beams with Stl Chan. Plates	2	1	40'	40'		19.12'	″				1904	″
29¾		Ditch	Box Culvert			2	2	5'	18.16'			″			″ ″	1910	″
38½		C. B. & Q. R.R. O.H.	T. P. G.			2	2		63'		18.33'					1897	″
43		Cattle Pass	Concrete			2			29.56'			″			″ ″	1906	″
44		Salt Creek	T. P. G.		Steel Floor Beams and Stringers	2	1	100'	100'	28.5'	[illegible]	″			″ ″	1906	″
46		Ditch	T. P. G.		″ ″ ″	2	1	55.75'	55.75'	28.5'	[illegible]	″			″ ″	1906	″
46½		I.C.R.R. O.H.				1	1	62.5'	62.5'	14'	18'	″					
54		St. Chas. Rd. R.	T. P. G.		Floor Beams - Stl Chan. Plates	2	1	73.83'	73.83'	28'	14.33	″		Under Street Xing	″ ″	1897	Yes
56		C.& N.W. R.R. T.R.		1.96'	″ ″ ″	2	1	107.5	107.5'	31'		″	226.87		″ ″	1910	″
57		Elgin Rd. R.	T. P. G.		Floor Beams - Stl Chan Plates	2	1	78'	81.0'	28'	15.8'	″		Under Street Xing	″ ″	1897	″
57		″ ″ ″	″ ″ ″		″ ″	1	1	78'	81'	14'	13.1'	″		Wye Track	″ ″	1908	″
64		Ditch	Flat Top Arch			2			55.83'						″ ″		NO

FIG. 263. "FORM D." STATEMENT OF RAILROAD BRIDGES, CULVERTS AND OVERHEAD CROSSINGS, CHICAGO TERMINALS

TABLE CLIV. SUMMARY OF RAILROAD UNDER CROSSING BRIDGES. ZONES A AND B
(Basis of 1912)

Railroad	Steam Railroad				Electric Railway				Street and Highway				Footway				Private								Others				Waterway												Total				Totals
																	Team				Foot								Movable				Fixed				Culverts								
	Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		
Zone	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Atchison, Topeka & Santa Fe Ry.							6				22																			1			1	3	1		4	4			5	8	29		42
Baltimore & Ohio R. R.							2				5															1			1	1				1			1				2	3	7		12
Baltimore & Ohio Chicago Terminal R. R.		1					17				46				1											1	1		1	2	2			7	1		1	45			2	56	68		126
Calumet, Hammond & Southeastern R. R.																																													
Chesapeake & Ohio Ry. of Indiana																																													
Chicago & Alton R. R.						1	7			1	31																				1						3	5			3	7	39		49
Chicago & Calumet River R. R.																																													
Chicago & Eastern Illinois R. R.																																		1								1			1
Chicago & Erie R. R.																														1												1			1
Chicago & Illinois Western R. R.																																		4				1				5			5
Chicago & North Western Ry.			3		1	1	60	1			217	41			5	2			6								2	1	1		1		1	3		1	27	65	1		30	69	295	46	440
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago			5				24		1		80				1				2								2		3				2				28	1			34	1	114		149
Chicago, Burlington & Quincy R. R.		1	4				11	1		1	41	2							1															2								4	57	3	64
Chicago Great Western R. R.																																		2				4				6			6
Chicago, Indiana & Southern R. R.										1																								1								2			2
Chicago, Indianapolis & Louisville Ry.																														1												1			1
Chicago Junction Ry.			2				16				47				1												1		2		2				1		1				3		70		73
Chicago, Milwaukee & St. Paul Ry.							11	1		1	38	13	1		1												1	4	3				1	2			7	16			12	19	51	18	100
Chicago River & Indiana R. R.			2				1				1																																4		4
Chicago, Rock Island & Pacific Ry.			2	3			17	1			53	2															1							2			14	6			14	8	73	6	101
Chicago Short Line Ry.																																													
Chicago Union Transfer Ry.																																													
Chicago, West Pullman & Southern R. R.																																													
Elgin, Joliet & Eastern Ry.				6						1																4			1	2				3				1			1	11		6	18
Grand Trunk Western Ry.			2				4				23											1												3			10	35			10	39	29		78
Illinois Central R. R.		1	4	2	2		15	2	1		54	8			1										2		3		2		1			2	1		33	31	1	5	40	34	80	17	171
Illinois Northern Ry.							1				1																		1				2								3		2		5
Indiana Harbor Belt R. R.		1	2	1			3				20	2						1												1				5			1	6			1	14	25	3	43
Lake Shore & Michigan Southern Ry.			6				23				64															1				1	1			1				2				5	94		99
Manufacturers' Junction Ry.				3				5				5								2																								15	15
Michigan Central R. R.																														1							7	4			7	5			12
Minneapolis, St. Paul & Sault Ste. Marie Ry.				1				1				6																						1				22				23		8	31
New York, Chicago & St. Louis R. R.							1				5																		1								4	5			5	5	6		16
Pere Marquette R. R.																																													
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.							14				44				1												1		1		2			1	1		1				2	1	63		66
Pittsburgh, Fort Wayne & Chicago Ry.			5		2		23				82				1										1				3	2			2	4				1			8	7	111		126
Pullman Railroad																																													
Wabash Railroad																																		2			7	14			7	16			23
Totals		4	37	16	5	2	256	12	2	5	874	79	1		12	2		1	9	2		1			3	7	12	5	20	13	10		9	50	5	1	149	268	2	5	189	351	1,217	122	1,879

TABLE CLV. SUMMARY OF RAILROAD OVER CROSSING BRIDGES. ZONES A AND B
(Basis of 1912)

Railroad	Steam Railroad				Electric Railway				Street and Highway				Footway				Private								Others				Signal				Totals				Totals	Grand Totals Over and Under
	Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Surf.		Elev.		Team				Foot				Surf.		Elev.		Surf.		Elev.		Surf.		Elev.			
																	Surf.		Elev.		Surf.		Elev.															
Zone	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Atchison, Topeka & Santa Fe Ry.	4*				2		1*		2		1*																						8a		2*		10b	52
Baltimore & Ohio R. R.		1											1																				1	1			2	14
Baltimore & Ohio Chicago Terminal R. R.	5	1	1		5		2		6																								16	1	3		20	146
Calumet, Hammond & Southeastern R. R.																																						
Chesapeake & Ohio Ry. of Indiana																																						
Chicago & Alton R. R.																																						49
Chicago & Calumet River R. R.																																						
Chicago & Eastern Illinois R. R.																																						1
Chicago & Erie R. R.																																						1
Chicago & Illinois Western R. R.		1																																1			1	6
Chicago & North Western Ry.	2	2			13		7		13	2													2						7	7	38	15	35	11	47	15	108	548
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	4*		2		3c		4		3d						2										1				6		8		17e		16		33f	182
Chicago, Burlington & Quincy R. R.		1	1	1	5	1	3		5	1																			1	4	12	1	11	7	16	2	36	100
Chicago Great Western R. R.					1				1																								2				2	8
Chicago, Indiana & Southern R. R.										1												1												2			2	4
Chicago, Indianapolis & Louisville Ry.																																						1
Chicago Junction Ry.			3		9		2						14												112								135		5		140	213
Chicago, Milwaukee & St. Paul Ry.	1*	1			6				5																				2	10	10		14g	11	10		35h	135
Chicago River & Indiana R. R.																																						4
Chicago, Rock Island & Pacific Ry.			3		1		2		1	2																			1		13		3	2	18		23	124
Chicago Short Line Ry.																																						
Chicago Union Transfer Ry.		1																																1			1	1
Chicago, West Pullman & Southern R. R.																																						
Elgin, Joliet & Eastern Ry.		1																																1			1	19
Grand Trunk Western Ry.		1																																1			1	79
Illinois Central R. R.	1		2		1		2		2	1	3*		8								1				2				14	5	6		29	6	13i		48j	219
Illinois Northern Ry.																																						5
Indiana Harbor Belt R. R.		3				1				5																								9			9	52
Lake Shore & Michigan Southern Ry.		1	1		1		2		1																					4	20		2	5	23		30	129
Manufacturers' Junction Ry.																																						15
Michigan Central R. R.																														4				4			4	16
Minneapolis, St. Paul & Sault Ste. Marie Ry.																																						31
New York, Chicago & St. Louis R. R.			3		1																												1		3		4	20
Pere Marquette R. R.																																						
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	4		1		4		4		4																								12		5		17	83
Pittsburgh, Fort Wayne & Chicago Ry.		2			12	1	2		12																					1	17		24	4	19		47	173
Pullman Railroad																																						
Wabash Railroad		1				1																												2			2	25
Totals	21k	17	17	1	64l	4	31m		55n	12	4*		23		2						1	1	2		115				31	35	124	16	310o	69	180p	17	576q	2,455r
Deduct for bridges counted twice																																						56
Net total																																						2,399s

* Tracks are depressed
a Includes 4 with depressed tracks
b " 6 " " "
c " 1 " " "
d " 1 " " "
e " 6 " " "
f " 6 " " "
g " 1 " " "

h Includes 1 with depressed tracks
i " 3 " " "
j " 3 " " "
k " 9 " " "
l " 1 " " "
m " 1 " " "
n " 1 " " "
o " 11 " " "

p Includes 5 with depressed tracks
q " 16 " " "
r " 16 " " "
s This is not the number of separate bridges, but the number of crossings of owned tracks by bridges. Where a bridge crosses the tracks of two or more owning companies it is counted as two or more bridges.

FIG. 264. BRIDGES. Bascule bridge of the Illinois Central Railroad, the Atchison, Topeka & Santa Fe Railway, and the Chicago & Alton Railroad, over the Chicago River at 31st Street and Archer Avenue.

FIG. 265. BRIDGES. Rolling lift bridge of the Baltimore & Ohio Chicago Terminal Railroad over the Chicago River at Taylor Street.

FIG. 266. BRIDGES. Swing bridge of the Illinois Central Railroad across the Sanitary Canal at Kedzie Avenue.

FIG. 267. BRIDGES. Protected plate-girder bridge separating crossing of the Pittsburgh, Fort Wayne & Chicago Railway and the Lake Shore & Michigan Southern Railway from the Illinois Central Railroad, at 75th Street and South Chicago Avenue.

FIG. 268. BRIDGES. Through plate-girder bridges over the Chicago & Western Indiana Railroad at 16th Street, separating crossings of the Lake Shore & Michigan Southern Railway, the Chicago, Rock Island & Pacific Railway and the St. Charles Air Line.

FIG. 269. BRIDGES. Through truss bridge of the Metropolitan Elevated Railway, separating crossing with the Chicago & North Western Railway, the Chicago, Milwaukee & St. Paul Railway and the Pittsburgh, Cincinnati. Chicago & St. Louis Railway.

FIG. 270. BRIDGES. Rolling lift bridges over the ship canal at Indiana Harbor, carrying the tracks of the Chicago, Indiana & Southern Railroad, the Lake Shore & Michigan Southern Railway, the Baltimore & Ohio Railroad and the Elgin, Joliet & Eastern Railway.

FIG. 271. BRIDGES. Plate-girder draw bridge of the Illinois Central Railroad over the Grand Calumet River at Riverdale.

FIG. 272. BRIDGES. Through plate-girder bridge of the Chicago & North Western Railway over street crossing at Avondale Station.

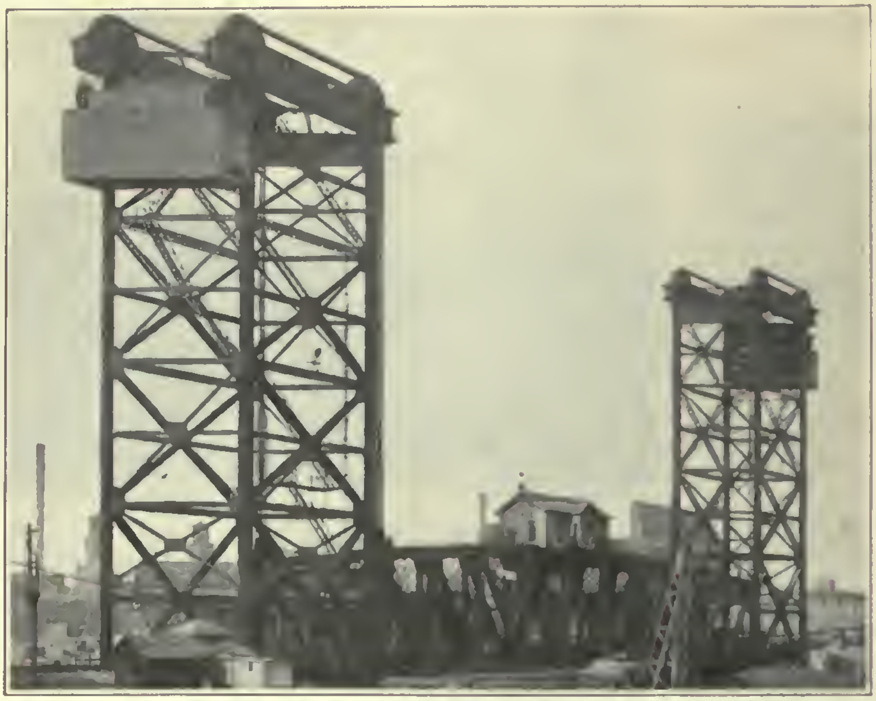


FIG. 273. BRIDGES. Lift bridge of the Chicago & Alton Railroad and the Pittsburgh, Fort Wayne & Chicago Railway, across the Chicago River at 20th Street and Stewart Avenue.

TABLE CLVI. STATISTICS OF TRACK ELEVATION OF STEAM RAILROADS IN THE CITY OF CHICAGO
December 31, 1914

Railroad	Elevation Completed or Under Construction		Ordinances Passed—Work not Started	
	Miles of Road-bed	Miles of Track	Miles of Road-bed	Miles of Track
1	2	3	4	5
Atchison, Topeka & Santa Fe Ry	4.76	9.52	.....	.....
Baltimore & Ohio R. R.	1.53	5.04	.....	.....
Baltimore & Ohio Chicago Terminal R. R.	12.46	40.36	.....	.....
Calumet, Hammond & Southeastern R. R.	......	....	.....	.....
Chesapeake & Ohio Ry. of Indiana	......	....	.....	.....
Chicago & Alton R. R.	4.05	28.47	.....	.....
Chicago & Calumet River R. R.	......	....	.....	.....
Chicago & Eastern Illinois R. R.	......	....	.....	.....
Chicago & Erie R. R.	......	....	.....	.....
Chicago & Illinois Western R. R.	0.92	1.84	.....	.....
Chicago & North Western Ry	29.64	210.98	4.28	21.72
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	16.71	186.12	4.42	21.03
Chicago, Burlington & Quincy R. R.	9.70	68.46	.....	.....
Chicago Great Western R. R.	......	....	.....	.....
Chicago, Indiana & Southern R. R.	......	....	.....	.....
Chicago, Indianapolis & Louisville Ry	......	....	.....	.....
Chicago Junction Ry	6.87	21.19	.....	.....
Chicago, Milwaukee & St. Paul Ry	14.41	78.93	2.45	9.67
Chicago River & Indiana R. R.	......	....	.....	.....
Chicago, Rock Island & Pacific Ry	12.20	48.24	4.20	16.12
Chicago Short Line Ry	......	....	.....	.....
Chicago Union Transfer Ry	......	....	.....	.....
Chicago, West Pullman & Southern R.R	......	....	.....	.....
Elgin, Joliet & Eastern Ry	......	....	.....	.....
Grand Trunk Western Ry	2.27	6.54	.....	.....
Illinois Central R. R. (Main Line)	8.43	93.34	.....	.....
Chicago, Madison & Northern R. R.	1.75	3.81	.....	.....
St. Charles Air Line	0.42	1.69	.....	.....
Kankakee & Eastern R. R.	0.50	1.00	.....	.....
Illinois Northern Ry	0.14	1.27	.....	.....
Indiana Harbor Belt R. R.	1.77	3.55	.....	.....
Lake Shore & Michigan Southern Ry	13.18	97.50	.....	.....
Manufacturers' Junction Ry	......	....	.....	.....
Michigan Central R. R.	......	....	.....	.....
Minneapolis, St. Paul & Sault Ste. Marie Ry. (Cent Term)	0.65	6.00	.....	.....
New York, Chicago & St. Louis R. R.	0.95	1.90	.....	.....
Pere Marquette R. R.	......	....	.....	.....
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	24.30	156.88	0.70	3.80
Englewood Connecting Ry				
Pittsburgh, Fort Wayne & Chicago Ry				
Pullman Railroad		....	.....	.....
Wabash Railroad	1.60	6.54	.....	.....
Totals	169.21	1,079.17	16.05	72.34

FIG. 274. EXTENT AND LOCATION OF THE ELEVATED STEAM RAILROAD LINES IN THE AREA OF INVESTIGATION

FIG. 275. TRACK ELEVATION. Reinforced concrete bridge of the Illinois Central Railroad at 71st Street.

FIG. 278. TRACK ELEVATION. Double track plate-girder span on the Chicago, Milwaukee & St. Paul Railway at Healy Station.

FIG. 276. TRACK ELEVATION. Concrete retaining walls on the Pittsburgh, Fort Wayne & Chicago Railway at 75th Street and Greenwood Avenue.

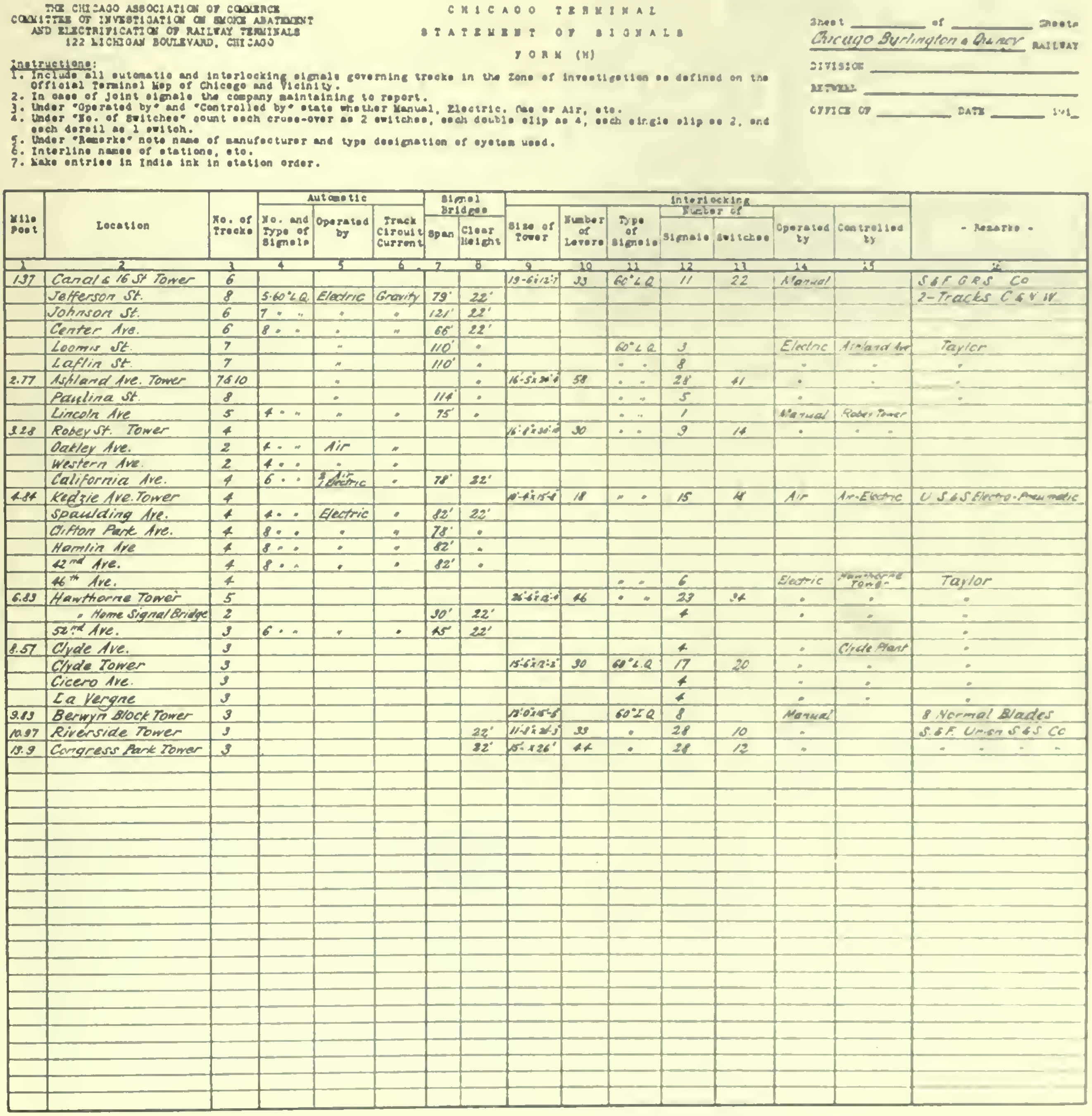
FIG. 279. TRACK ELEVATION. Deck plate-girder bridge of the Chicago & North Western Railway at Harlem Avenue, Oak Park.

FIG. 277. TRACK ELEVATION. Masonry retaining wall of the Chicago & North Western Railway at Kinzie Street and North Francisco Avenue.

FIG. 280. TRACK ELEVATION. Concrete retaining wall of the Chicago & North Western Railway at East Avenue, Oak Park.

of the Illinois Central Railroad north of 67th Street. Illustrations of typical signals and signal bridges, as used by different railroad companies within the Chicago District, are presented as figs. 282 to 289, inclusive.

Interlocking towers are located at principal railroad crossings or junction points. They vary from small buildings equipped with a single lever, to buildings of considerable size. While many of the towers in the Chicago District are operated electrically, some of the largest are operated by hand. The Lake Street interlocking plant of the Chicago & North Western Railway is the largest within the district. It is electrically operated and controls the tracks entering the passenger terminal on Madison Street. It has 212 levers, of which 171 are in use at the present time, and controls 67 signals



THE CHICAGO ASSOCIATION OF COMMERCE
COMMITTEE OF INVESTIGATION ON SMOKE ABATEMENT
AND ELECTRIFICATION OF RAILWAY TERMINALS
122 MICHIGAN BOULEVARD, CHICAGO

CHICAGO TERMINAL
STATEMENT OF SIGNALS
FORM (H)

Sheet ________ of ________ Sheets
Chicago Burlington & Quincy RAILWAY
DIVISION ________________
BETWEEN ________________
OFFICE OF ________ DATE ________ 191_

Instructions:
1. Include all automatic and interlocking signals governing tracks in the Zone of investigation as defined on the Official Terminal Map of Chicago and Vicinity.
2. In case of joint signals the company maintaining to report.
3. Under "Operated by" and "Controlled by" state whether Manual, Electric, Gas or Air, etc.
4. Under "No. of Switches" count each cross-over as 2 switches, each double slip as 4, each single slip as 2, and each derail as 1 switch.
5. Under "Remarks" note name of manufacturer and type designation of system used.
6. Interline names of stations, etc.
7. Make entries in India ink in station order.

Mile Post	Location	No. of Tracks	Automatic			Signal Bridges		Interlocking							- Remarks -
			No. and Type of Signals	Operated by	Track Circuit Current	Span	Clear Height	Size of Tower	Number of Levers	Type of Signals	Number of		Operated by	Controlled by	
											Signals	Switches			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.37	Canal & 16 St Tower	6						19-6x12-7	33	60° L Q	11	22	Manual		S & F G R S Co
	Jefferson St.	8	5-60° L Q.	Electric	Gravity	79'	22'								2-Tracks C & N W
	Johnson St.	6	7 " "	"	"	121'	22'								
	Center Ave.	6	8 " "	"	"	66'	22'								
	Loomis St.	7		"		110'	"			60° L Q	3		Electric	Ashland Ave	Taylor
	Laflin St.	7		"		110'	"			" "	8		"	"	"
2.77	Ashland Ave. Tower	7 & 10		"			"	16-5x30-4	58	" "	28	41	"	"	"
	Paulina St.	8		"		114'	"			" "	5		"		"
	Lincoln Ave	5	4 " "	"	"	75'	"			" "	1		Manual	Robey Tower	
3.28	Robey St. Tower	4						16-8x30-6	30	" "	9	14	"	" "	
	Oakley Ave.	2	4 " "	Air	"										
	Western Ave.	2	4 " "	"	"										
	California Ave.	4	6 " "	5 Air 1 Electric	"	78'	22'								
4.84	Kedzie Ave. Tower	4						10-4x15-4	18	" "	15	14	Air	Air-Electric	U S & S Electro-Pneumatic
	Spaulding Ave.	4	4 " "	Electric	"	82'	22'								
	Clifton Park Ave.	4	8 " "	"	"	78'	"								
	Hamlin Ave	4	8 " "	"	"	82'	"								
	42nd Ave.	4	8 " "	"	"	82'	"								
	46th Ave.	4								" "	6		Electric	Hawthorne Tower	Taylor
6.83	Hawthorne Tower	5						26-6x12-4	46	" "	23	34	"	"	"
	" Home Signal Bridge	2				30'	22'				4		"	"	"
	52nd Ave.	3	6 " "	"	"	45'	22'								"
8.57	Clyde Ave.	3									4		"	Clyde Plant	"
	Clyde Tower	3						15-6x12-2	30	60° L Q	17	20	"	"	"
	Cicero Ave.	3									4		"	"	"
	La Vergne	3									4		"	"	"
9.83	Berwyn Block Tower	3						12-0x15-5		60° L Q	8		Manual		8 Normal Blades
10.97	Riverside Tower	3					22'	11-8x24-5	33	"	28	10	"		S & F Union S & S Co
13.9	Congress Park Tower	3					22'	15-x26'	44	"	28	12	"		" " " "

FIG. 281. "FORM H." STATEMENT OF SIGNALS, CHICAGO TERMINALS

TABLE CLVII. SUMMARY OF STATISTICAL FACTS RELATING TO SIGNALS, SIGNAL BRIDGES AND INTERLOCKING PLANTS, BY ROADS. CITY OF CHICAGO. ZONE A
(Basis of 1912)

Railroad	Automatic Signals—Number								Signal Bridges					Interlocking											
	Type				Operated By		Track Circuit			Span		Clear Height		Towers		Number			No. Plants Operated By					No. Plants Controlled By	
	Semaphore									Feet															
	Upper Quad.	Lower Quad.	Disc	Total	Electricity	Other	D. C.	A. C.	Number	Max.	Min.	Max.	Min.	Number	Floor Area Sq. Ft.	Levers	Switches	Signals	Electricity	Manual	Air	Other	Total	Elec. Mech.	Other Means
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Atchison, Topeka & Santa Fe Ry.*																									
Baltimore & Ohio R. R.														1		20	6	6		1			1		1
Baltimore & Ohio Chicago Terminal R. R.	6	21	2	29	29		29		1	45	45	22	22	3	2,708	212	114	111		2	1		3		3
Calumet, Hammond & Southeastern R. R.*																									
Chesapeake & Ohio Ry. of Indiana*																									
Chicago & Alton R. R.		3		3	3		3		3	116	34	24	24	2	610	91	55	49	1	2			3	1	2
Chicago & Calumet River R. R.*																									
Chicago & Eastern Illinois R. R.*																									
Chicago & Erie R. R.*																									
Chicago & Illinois Western R. R.*																									
Chicago & North Western Ry.	106	54	163	323	311	12	323		49	113	31	25	22	14	7,007	1,154	689	427	10	2	2		14	12	2
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	7	50		57	53	4	57		9	105	52	27	20	14	4,981	585	564	355	1	8	5		14	4	10
Chicago, Burlington & Quincy R. R.		66		66	56	10	66		12	121	66	22	22	4	1,330	139	95	80	1	2	1		4	4	
Chicago Great Western R. R.*																									
Chicago, Indiana & Southern R. R.*																									
Chicago, Indianapolis & Louisville Ry.*																									
Chicago Junction Ry.														2	280	9	3	6		2			2	2	
Chicago, Milwaukee & St. Paul Ry.	52			52	52		47	5	19	86	48	26	22	15	4,222	431	306	245	5	10	1		16	4	12
Chicago River & Indiana R. R.*																									
Chicago, Rock Island & Pacific Ry.	17	32	27	76	76		66	10	14	96	60	25	21	6	2,147	297	184	161	5	1			6	5	1
Chicago Short Line Ry.*																									
Chicago Union Transfer Ry.*																									
Chicago, West Pullman & Southern R. R.*																									
Elgin, Joliet & Eastern Ry.*																									
Grand Trunk Western Ry.																									
Illinois Central R. R.		28	134	162	162		162		25	214	37	23	20	7	3,636	492	312	212	1	6			7	5	2
Illinois Northern Ry.*																									
Indiana Harbor Belt R. R.														1	238	24	13	12		1			1		1
Lake Shore & Michigan Southern Ry.	30			30	30		30		9	96	66	21	21	3	1,270	362	185	160	2	1			3	2	1
Manufacturers' Junction Ry.*																									
Michigan Central R. R.	10			10	10		10																		
Minneapolis, St. Paul & Sault Ste. Marie Ry.*																									
New York, Chicago & St. Louis R. R.														1	430	16	4	6	1				1		1
Pere Marquette R. R.*																									
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.		1		1	1		1							5	936	104	41	55		5			5		5
Pittsburgh, Fort Wayne & Chicago Ry.	70			70	70		70		19	73	47	22	22	8	3,851	508	213	190	1	7			8	1	7
Pullman Railroad*																									
Wabash Railroad*																									
Totals	298	255	326	879	853	26	864	15	160	214	31	27	20	86	33,646	4,447	2,784	2,075	28	50	10		88	40	48

* Have nothing embraced by this form.

and 167 switches. From this tower are directed the movements of 345 scheduled passenger trains per day, in addition to the movements of light engines and coaches to and from their yards.

The state line tower of the Chicago & Western Indiana Railroad, at the Illinois-Indiana State Line, is one of the largest manually operated towers in the United States, having 186 levers, and controlling 69 signals and 75 switches. The operation of this tower requires the constant services of six men.*

Views of interlocking towers in the Area of Investigation are presented as figs. 290 to 293 inclusive.

201.10 Fences, Cattle-Guards and Signs: The railroads in the Chicago District were requested to furnish information concerning the character and extent of fence enclosing their right-of-way, and concerning all cattle-guards and track signs used along their lines within the Area of Investigation. For this purpose each railroad was supplied with copies of "Form K," "Statement of Fences, Cattle-guards and Signs," a reproduction of which is presented as fig. 294.

FIG. 282. SIGNALS. Disc signal ("Banjo" type) on the Illinois Central Railroad near 76th Street.

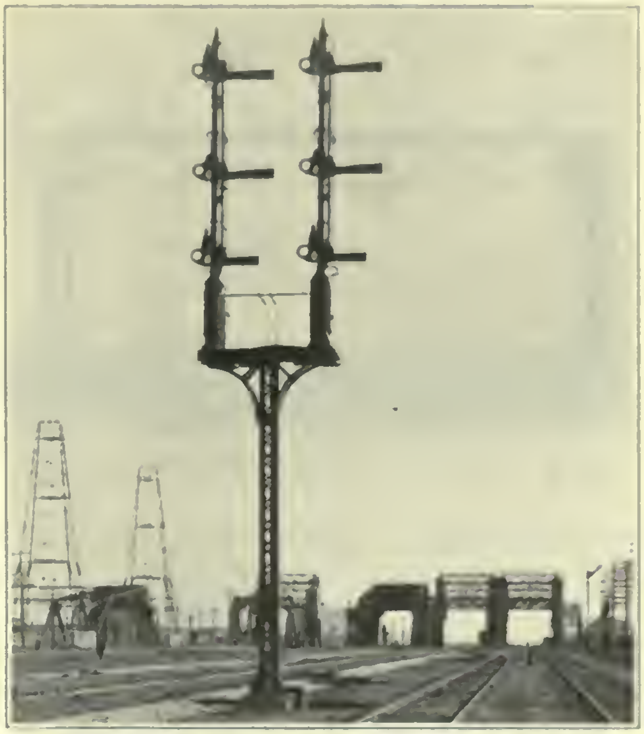


FIG. 283. SIGNALS. Upper quadrant semaphore signals controlling crossing of the ship canal bridges of the Lake Shore & Michigan Southern Railway, west of Indiana Harbor.

The information obtained from the railroad reports concerning fences, cattle-guards and signs was retabulated and summarized as in the case of other similar data. The complete summary, by roads, is presented as tables CLVIII and CLIX.

An inspection of tables CLVIII and CLIX shows that approximately 70 per cent of the railroad right-of-way in Zone A (the city of Chicago) is protected by fences, walls or buildings, and in Zone B approximately 65 per cent of the right-of-way is thus protected. Much of the elevated road-bed is protected by stone or concrete retaining walls. The usual form of protection in the Chicago District consists of fencing of various forms, the most common being woven wire, usually 4 feet, 6 inches, in height and fastened to wood or concrete posts set at intervals of from

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* These data relating to interlocking plants are on the basis of 1912

FIG. 284. SIGNALS. Standard signal bridge on the Pittsburgh, Fort Wayne & Chicago Railway, near Drexel Avenue.

FIG. 285. SIGNALS. Double track automatic signals on the Chicago, Milwaukee & St. Paul Railway, near Healy Station.

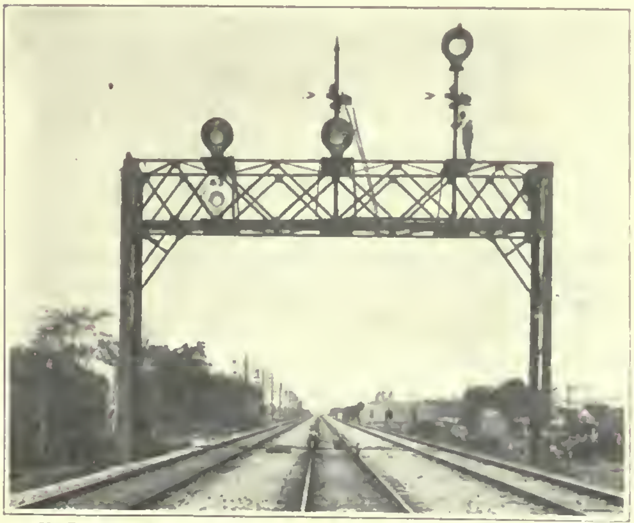


FIG. 286. SIGNALS. Signal bridge on the Chicago & North Western Railway, near Rosehill Station.

FIG. 287. SIGNALS. Standard signal bridge on the Illinois Central Railroad near Riverdale.

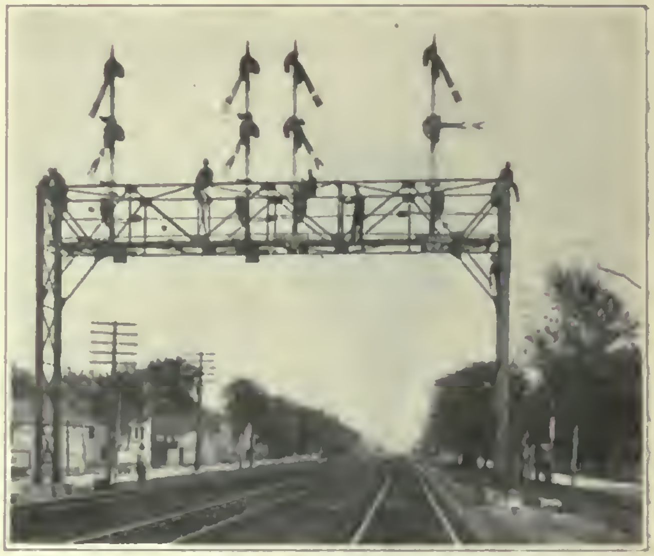


FIG. 288. SIGNALS. Three track signal bridge on the Chicago, Burlington & Quincy Railroad at La Grange, Ill.

FIG. 289. SIGNALS. Signal bridge on the St. Charles Air Line near Clark Street.

10 to 16 feet. Cattle-guards are little used within the city, since it is recognized that they afford practically no protection against persons entering upon the right-of-way and there is almost no need of such protection against animals.

201.11 Main Passenger Terminals: There are in the city of Chicago six large passenger terminals. This number does not include the Randolph Street suburban terminal of the Illinois Central Railroad. The location of each of these terminals and the routes over which they are reached are shown by the map presented as fig. 295.

The passenger terminals of Chicago may be divided into three groups, the first comprising the Chicago & North Western Station and the Union Station; the second, the La Salle Street, Grand Central and Dearborn stations; and the third, the Central Station of the Illinois Central Railroad.

The following descriptions of each of the six large passenger terminals are based on the conditions existing in the year 1912. Since that date, the Chicago & Eastern Illinois Railroad has changed its terminal from the La Salle Street

FIG. 290. INTERLOCKING PLANTS. Lake Street interlocking tower of the Chicago & North Western Railway. This is the largest plant of its kind in Chicago.

FIG. 292. INTERLOCKING PLANTS. State line tower of the Chicago & Western Indiana Railroad near Hammond, Ind. This is one of the largest manual interlocking plants in the United States.

FIG. 291. INTERLOCKING PLANTS. 43d Street interlocking tower of the Illinois Central Railroad. This plant is typical of a number of mechanically operated interlockers throughout the Area of Investigation.

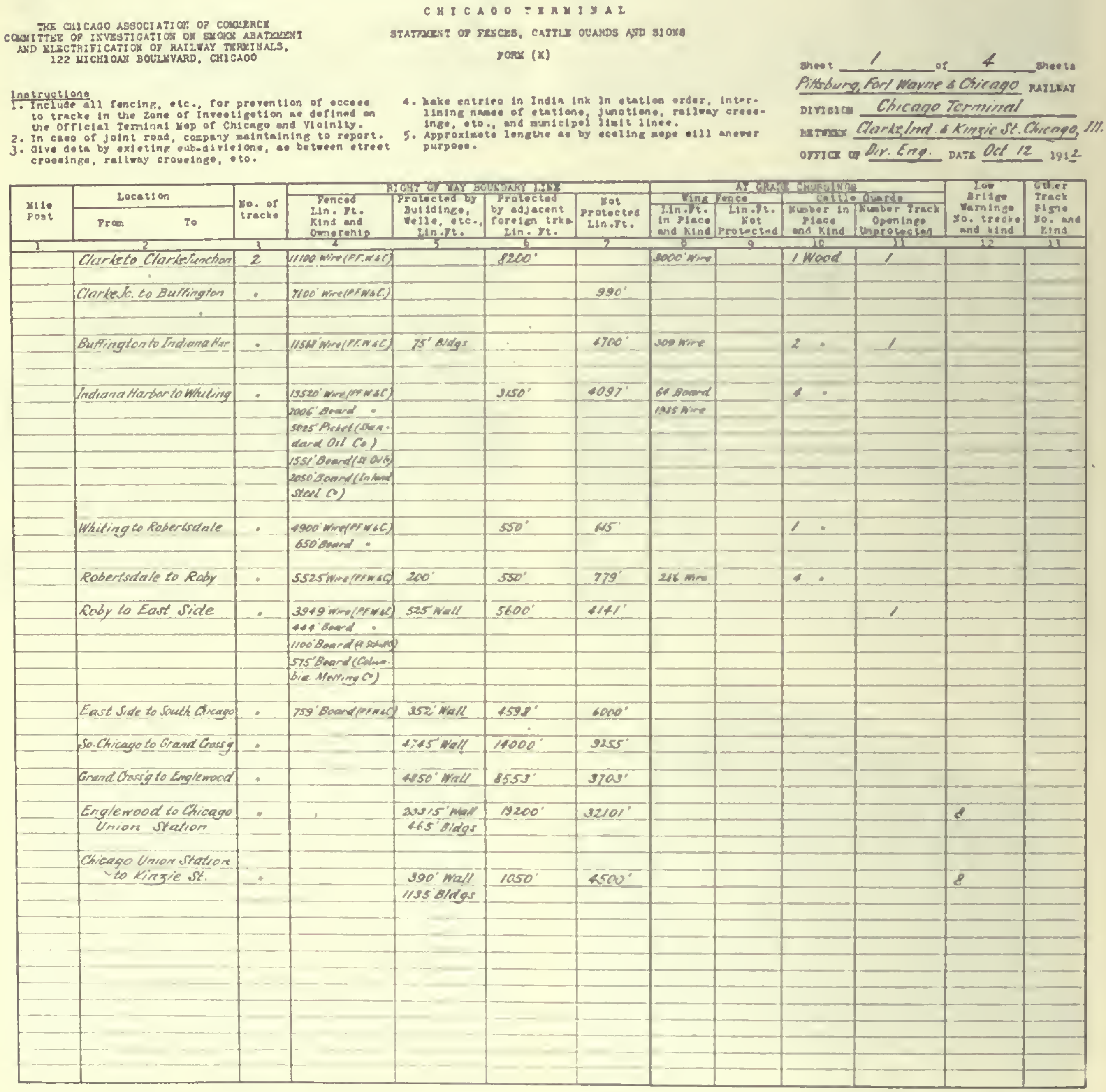
FIG. 293. INTERLOCKING PLANTS. Interlocking tower of the Lake Shore & Michigan Southern Railway west of Indiana Harbor Station. This plant controls signals governing the lift bridges over the ship canal.

Station to the Dearborn Station, and the Minneapolis, St. Paul & Sault Ste. Marie Railway has changed from the Central Station to the Grand Central Station.

Chicago & North Western Passenger Station (Madison Street Terminal)

The Chicago & North Western Railway passenger terminal is located between Clinton and Canal streets, with its main entrance on Madison Street. An exterior view of this terminal is shown by fig. 296.

This station was opened for traffic June 4, 1911. The building and the tracks approaching it are owned and controlled exclusively by the Chicago & North Western Railway. During the year 1912, an average of 70 through passenger trains and 102 suburban passenger trains arrived at, and 71 through passenger trains and 102 suburban



THE CHICAGO ASSOCIATION OF COMMERCE
COMMITTEE OF INVESTIGATION ON SMOKE ABATEMENT
AND ELECTRIFICATION OF RAILWAY TERMINALS,
122 MICHIGAN BOULEVARD, CHICAGO

CHICAGO TERMINAL
STATEMENT OF FENCES, CATTLE GUARDS AND SIGNS
FORM (K)

Sheet 1 of 4 Sheets
Pittsburg, Fort Wayne & Chicago RAILWAY
DIVISION Chicago Terminal
BETWEEN Clarke, Ind. & Kinzie St. Chicago, Ill.
OFFICE OF Div. Eng. DATE Oct 12 1912

Instructions
1. Include all fencing, etc., for prevention of access to tracks in the Zone of Investigation as defined on the Official Terminal Map of Chicago and Vicinity.
2. In case of joint road, company maintaining to report.
3. Give data by existing sub-divisions, as between street crossings, railway crossings, etc.
4. Make entries in India ink in station order, interlining names of stations, junctions, railway crossings, etc., and municipal limit lines.
5. Approximate lengths as by scaling maps will answer purpose.

Mile Post	Location From To	No. of tracks	RIGHT OF WAY BOUNDARY LINE Fenced Lin. Ft. Kind and Ownership	Protected by Buildings, Walls, etc., Lin. Ft.	Protected by adjacent foreign trks. Lin. Ft.	Not Protected Lin. Ft.	AT GRADE CROSSINGS Wing Fence Lin. Ft. in Place and Kind	Lin. Ft. Not Protected	Cattle Guards Number in Place and Kind	Number Track Openings Unprotected	Low Bridge Warnings No. tracks and kind	Other Track Signs No. and Kind
1	2	3	4	5	6	7	8	9	10	11	12	13
	Clarke to Clarke Junction	2	11100 Wire (P.F.W.&C.)		8200'		8000' Wire		1 Wood	1		
	Clarke Jc. to Buffington	"	7100' Wire (P.F.W.&C.)			990'						
	Buffington to Indiana Har	"	11568' Wire (P.F.W.&C.)	75' Bldgs		4700'	309 Wire		2 "	1		
	Indiana Harbor to Whiting	"	13520' Wire (P.F.W.&C.) 2006' Board " 5025' Picket (Standard Oil Co.) 1551' Board (St. Oil Co.) 2050' Board (Inland Steel Co.)		3150'	4097'	64 Board 1915 Wire		4 "			
	Whiting to Robertsdale	"	4900' Wire (P.F.W.&C.) 650' Board "		550'	615'			1 "			
	Robertsdale to Roby	"	5525 Wire (P.F.W.&C.)	200'	550'	779'	216 Wire		4 "			
	Roby to East Side	"	3949 Wire (P.F.W.&C.) 444' Board " 1100' Board (A. Schultz) 575' Board (Columbia Melting Co.)	525' Wall	5600'	4141'				1		
	East Side to South Chicago	"	759' Board (P.F.W.&C.)	352' Wall	4598'	6000'						
	So. Chicago to Grand Cross'g	"		4745' Wall	14000'	9255'						
	Grand Cross'g to Englewood	"		4850' Wall	8553'	3703'						
	Englewood to Chicago Union Station	"		23315' Wall 465' Bldgs	19200'	32101'					8	
	Chicago Union Station to Kinzie St.	"		390' Wall 1135' Bldgs	1050'	4500'					8	

FIG. 294. "FORM K." STATEMENT OF RAILROAD FENCES, CATTLE-GUARDS AND SIGNS, CHICAGO TERMINALS

TABLE CLVIII. SUMMARY OF RAILROAD FENCES, CATTLE-GUARDS AND SIGNS, BY ROADS. ZONE A
(Basis of 1912)

Railroad	Right-of-way Boundary Line—Miles										At Grade Crossing—No.			Signs—Number				
	Fence						Protected by Bldgs. Walls Etc.	Protected by Adjacent Tracks	Not Protected	Wing Fence	Cattle-guards		Track Op'gs Not Protected	Low Bridge	Crossing	Whistle	Other	Total
	Board	Wire	Other	Total	Fence Owned						Wooden	Total						
					Private	R. R. Co.												
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Atchison, Topeka & Santa Fe Ry.	1 80	1.35	0 64	3.79		3 79		4 59	7 27				14					
Baltimore & Ohio R. R.		4 81		4.81		4.81	1 42	2.92	6 98				27		22			22
Baltimore & Ohio Chicago Terminal R. R.	0 08	7 16		7 24		7.24		17.74	13.87				33	9	28			37
Calumet, Hammond & Southeastern R. R.†													7†		1			1
Chesapeake & Ohio Ry. of Indiana																		
Chicago & Alton R. R.	1 89	0 08	0 02	1 99	0 89	1.10	1.45	3.69	9.90				17	8			9	17
Chicago & Calumet River R. R.	0.74			0.74	0 74		0 05	0.23	1.34									
Chicago & Eastern Illinois R. R.																		
Chicago & Erie R. R.																		
Chicago & Illinois Western R. R.																		
Chicago & North Western Ry.	5.14	40 84	0.76	46 74		46.74	21.57	8.97	3.26	0.37	22	22	52	8	3	19	26	56
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	4 38	25.30		29 68		29 68	8.12	29.59	40.05	0 05	4	4		8	73		2	83
Chicago, Burlington & Quincy R. R.	1 26	0.62		1.88		1 88	4.29	2.66	2.33				5					
Chicago Great Western R. R.																		
Chicago, Indiana & Southern R. R.																		
Chicago, Indianapolis & Louisville Ry.																		
Chicago Junction Ry.*	0.55			0 55	0.55		4.92	5.40	2 52				8	1				1
Chicago, Milwaukee & St. Paul Ry.	12.72	20.41	0 29	33 42	3.86	29.56	13.38	3 62	12.02				179	17	22	9	6	54
Chicago River & Indiana R. R.	0.11			0.11	0.11			2.84	2.73				10					
Chicago, Rock Island & Pacific Ry.		27 07		27.07		27.07	10.02	12.54	9.38				81					
Chicago Short Line Ry.	0.63			0.63	0.63				1.28				3					
Chicago Union Transfer Ry.								1.99	5.12				6		3			3
Chicago, West Pullman & Southern R. R.	0.66			0.66	0.66		0.28	0.19	1.57				11					
Elgin, Joliet & Eastern Ry.		0.87	2.50	3.37	2.50	0.87		0.28	0.23	0.13			7		16	1	14	31
Grand Trunk Western Ry.	0.96	0 38		1 34	0.77	0.57	0.21	3.62	11 58				22		16	11	30	57
Illinois Central R. R.	0.79	15 12		15.91	0.79	15 12	16.01	5 64	13.81				63	4	49			53
Illinois Northern Ry.									7.40				16		8			8
Indiana Harbor Belt R. R.	0.10	3.37	0.02	3.49	0.01	3.45	1.56	3 79	2.81	0 05			8		8		18	26
Lake Shore & Michigan Southern Ry.	2.87			2 87		2.87	7.32	15.25	1.61				3	2				2
Manufacturers' Junction Ry.																		
Michigan Central R. R.	0.20	3 96	0 13	4.29	0 34	3.95	0.34	2.88	0.83	0.05	7	7	21		3		3	6
Minneapolis, St. Paul & Sault Ste. Marie Ry.																		
New York, Chicago & St. Louis R. R.	2.10	5.55		7.65	0.90	6.75		3.67	5.21	0.01			9		5			5
Pere Marquette R. R.																		
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	0.85	10.38	0.17	11.40	0.29	11 11	2.16	13.23	11.66	0.24	4	4	51	14				14
Pittsburgh, Fort Wayne & Chicago Ry.	2.18	10.59	0.56	13.33	1.73	11.60	6.94	12.26	31.73	0.15	18	18	53	8	9			17
Pullman Railroad	2.30	0.17	1.23	3.70	1.15	2.55	0.66		4.25				6				3	3
Wabash Railroad	0.05	0.24		0.29	0.25	0.04		3.30	4.64				7		4	7	12	23
Totals	42.36	178.27	6.32	226.95	16.20	210.75	100.70	160.89	215.98	1.05	55	55	719	79	270	47	123	519

* Does not include Stock Yards or Central Manufacturing District.

† All inside of fence surrounding works.

TABLE CLIX. SUMMARY OF RAILROAD FENCES, CATTLE-GUARDS AND SIGNS, BY ROADS. ZONE B
(Basis of 1912)

Railroad	Right-of-way Boundary Line—Miles										At Grade Crossing—No.				Signs—Number				
	Fence						Protected by Bldgs. Walls Etc.	Protected by Adjacent Tracks	Not Protected	Wing Fence	Cattle-Guards			Track Op'gs Not Protected	Low Bridge	Crossing	Whistle	Other	Total
	Board	Wire	Other	Total	Fence Owned						Wooden	Other	Total						
					Private	R. R. Co.													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Atchison, Topeka & Santa Fe Ry.		5.54		5.54		5.54		3.13	2.98	0.04		8	8	3		4			4
Baltimore & Ohio R. R.								17.43	3.44					11		1			1
Baltimore & Ohio Chicago Terminal R. R.	2.25	27.54	0.09	29.88	3.19	26.69	0.25	6.16	55.87	0.12	6		6	148	6	117	21	49	193
Calumet, Hammond & Southeastern R. R.																			
Chesapeake & Ohio Ry. of Indiana		1.41		1.41		1.41		1.41						9		4			4
Chicago & Alton R. R.		2.21		2.21		2.21			9.30	0.01	1		1	1			2	7	9
Chicago & Calumet River R. R.																			
Chicago & Eastern Illinois R. R.		2.51		2.51		2.51			7.25					5					
Chicago & Erie R. R.	0.08	2.25		2.33	0.08	2.25	0.21	3.63	1.99					20		15			15
Chicago & Illinois Western R. R.		3.16		3.16		3.16		5.45	2.64					11				4	4
Chicago & North Western Ry.	0.52	38.17		38.69	0.80	37.89	10.34	2.16	1.95	0.43	20		20	28	2	10	42	58	112
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago		1.41		1.41		1.41	0.05	3.11	1.25	0.01	2		2			3			3
Chicago, Burlington & Quincy R. R.	2.36	0.48		2.84		2.84		0.36	10.52					17		1			1
Chicago Great Western R. R.	0.16	5.34	0.06	5.56	0.75	4.81	0.41	1.13	2.95	0.07	7		7	87		15	20	6	41
Chicago, Indiana & Southern R. R.	1.14	4.70		5.84	2.30	3.54	0.10	7.01	7.52					13		10			10
Chicago, Indianapolis & Louisville Ry.	0.05	2.20		2.25	0.44	1.81	0.20	1.39	4.15	0.02				18			2	13	15
Chicago Junction Ry.																			
Chicago, Milwaukee & St. Paul Ry.	0.36	16.73		17.09	0.04	17.05	1.98	0.11	5.18	0.06	3	1	4	21		37	18	10	65
Chicago River & Indiana R. R.																			
Chicago, Rock Island & Pacific Ry.		7.09		7.09		7.09	0.55	0.31	2.52					9					
Chicago Short Line Ry.																			
Chicago Union Transfer Ry.									7.00					3		1			1
Chicago, West Pullman & Southern R. R.																			
Elgin, Joliet & Eastern Ry.	1.00	2.92	1.09	5.01	1.15	3.86	0.07	16.82	27.06	0.05				29		102	32	95	229
Grand Trunk Western Ry.	0.13	17.41	0.02	17.56	1.45	16.11	0.16	1.46	5.38	0.27	25		25	34		35	39	63	137
Illinois Central R. R.		21.42	0.82	22.24	0.82	21.42			5.78	0.20	9		9	48		44			44
Illinois Northern Ry.																			
Indiana Harbor Belt R. R.	3.56	26.90	0.38	30.84	3.32	27.52	0.74	10.54	37.27	0.04				88	16	58	20	109	203
Lake Shore & Michigan Southern Ry.	1.29	4.24		5.53		5.53		19.30	1.38	0.01				10		6			6
Manufacturers' Junction Ry.								3.20	3.20					3					
Michigan Central R. R.		16.24	0.10	16.34		16.34	0.01	2.31	1.91	0.12	12		12	118		34		16	50
Minneapolis, St. Paul & Sault Ste. Marie Ry.		11.82		11.82		11.82			2.52	0.11	24		24	8		15	26	40	81
New York, Chicago & St. Louis R. R.	0.09	7.11	0.09	7.29		7.29	0.13	3.78	1.46	0.05				19		11			11
Pere Marquette R. R.																			
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.		10.95		10.95		10.95		0.52	2.28	0.13	7		7	22					
Pittsburgh, Fort Wayne & Chicago Ry.	1.24	25.11	0.95	27.30	1.63	25.67	0.05	3.02	5.37	1.07	26	1	27	22		28			28
Pullman Railroad																			
Wabash Railroad		2.71		2.71		2.71		2.43	9.67	0.17	10		10	14		13	18	18	49
Totals	14.23	267.57	3.60	285.40	15.97	269.43	15.25	116.20	229.79	2.98	152	10	162	819	24	564	240	488	1,316

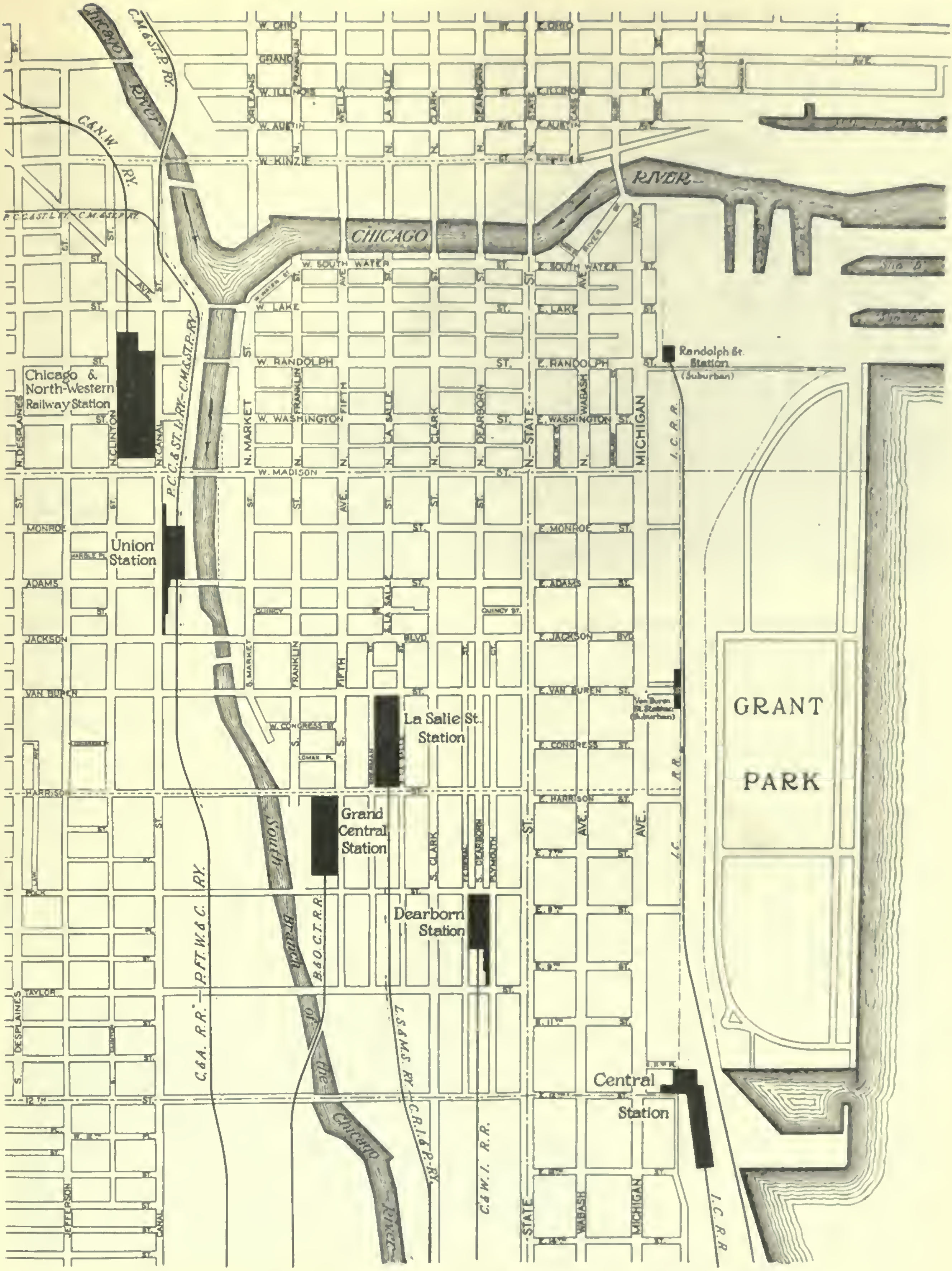


FIG. 295. LOCATION OF PASSENGER TERMINALS IN THE CITY OF CHICAGO

FIG. 296. CHICAGO & NORTH WESTERN RAILWAY PASSENGER STATION
(Madison Street Terminal)

passenger trains departed from, this terminal every week day. The total incoming and outgoing passengers in 1912 was 14,582,315.*

Illinois Central Passenger Station
(*Central Station*)

The Illinois Central Station, located at East 11th Place and Indiana Avenue, is shown by fig. 297.

This passenger station was opened for traffic April 17, 1893, and an annex was constructed in 1903. Practically all of the annex and most of the main building are used for the general offices of the Illinois Central Railroad. This station is used for through passenger trains only, suburban trains having other arrangements for their accommodation. The building and tracks approaching it are owned by the Illinois Central Railroad, but the station is also used as a passenger terminal by the following railroads:

1. The Michigan Central Railroad, which has trackage rights over the Illinois Central Railroad from Kensington Station to the Illinois Central Station, a distance of 13 miles.
2. The Cleveland, Cincinnati, Chicago & St. Louis Railway (Big Four), which has its trains brought into Chicago by the Illinois Central Railroad from Kankakee, Ill., a distance of 54 miles.
3. The Minneapolis, St. Paul & Sault Ste. Marie Railway (Soo Line), which has trackage rights over the lines of the Illinois Central Railroad from Forest Park, Ill., to the Illinois Central Station, a distance of 13.6 miles.†

During the year 1912, an average of 42 through passenger trains arrived at, and 43 departed from, the Illinois Central Station every week day. The total number of incoming and outgoing passengers handled during 1912 was 1,594,542.

Dearborn Station

The Dearborn Station, located between Federal Street and Plymouth Court, was opened for service May 18, 1885. It is shown by fig. 298.

This station, with the tracks approaching it, is owned by the Chicago & Western Indiana Railroad but it is also used as a passenger terminal by the following railroads:

FIG. 297. ILLINOIS CENTRAL RAILROAD PASSENGER TERMINAL
(Central Station)

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*A detailed description of this terminal may be found in the Journal of the Western Society of Engineers for December, 1911.

† This road changed to the Grand Central Station, April 1, 1914.

FIG. 298. DEARBORN STATION

1. The Atchison, Topeka & Santa Fe Railway, which has rights over the tracks of the Chicago & Western Indiana Railroad from Chicago & Western Indiana Junction to Dearborn Station, a distance of 1.2 miles.

2. The Chesapeake & Ohio Railway of Indiana, which has trackage rights over the lines of the Chicago & Western Indiana Railroad from the Illinois-Indiana State Line, near Hammond, Ind., to the Dearborn Station, a distance of 19.8 miles.

3. The Chicago & Erie Railroad, which has rights over the tracks of the Chicago & Western Indiana Railroad from the Illinois-Indiana State Line, near Hammond, Ind., to Dearborn Station, a distance of 19.8 miles.

4. The Chicago, Indianapolis & Louisville Railway (Monon), which has rights over the tracks of the Chicago & Western Indiana Railroad from the Illinois-Indiana State Line, near Hammond, Ind., to Dearborn Station, a distance of 19.8 miles.

FIG 299. GRAND CENTRAL STATION

5. The Grand Trunk Western Railway, which has rights over the tracks of the Chicago & Western Indiana Railroad from Chicago & Western Indiana Junction, near 49th and Wallace streets, to the Dearborn Station, a distance of 4.9 miles.

6. The Wabash Railroad, which has rights over the tracks of the Chicago & Western Indiana Railroad from Chicago & Western Indiana Junction, near 75th and Wallace streets, to the Dearborn Station, a distance of 8.0 miles; also from the Illinois-Indiana State Line, near Hammond, Ind., to the Dearborn Station, a distance of 19.8 miles.

During the year 1912, an average of 39 through passenger trains and 28 suburban trains arrived at, and 37 through passenger trains and 29 suburban trains departed from, this station every week day. The total number of incoming and outgoing passengers handled during 1912 was 4,064,457.

Grand Central Station

The Grand Central Station, located at the southwest corner of Harrison Street and Fifth Avenue, was opened for service December 10, 1890. It is shown by fig. 299.

This station was constructed by the Chicago & Northern Pacific Railroad, now the Baltimore &

FIG. 300. UNION STATION

Ohio Chicago Terminal Railroad. A considerable portion of the building is occupied by the general offices of the Baltimore & Ohio Chicago Terminal Railroad and the Chicago Great Western Railroad, and by division offices of the Baltimore & Ohio Railroad. The building and tracks approaching it are now owned by the Baltimore & Ohio Chicago Terminal Railroad, which uses it as a terminal, as do also the following railroads:

1. The Chicago Great Western Railroad, which has rights over the tracks of the Baltimore & Ohio Chicago Terminal Railroad from Forest Park, Ill., to the terminal, a distance of 10.8 miles.

2. The Baltimore & Ohio Railroad, which has rights over the tracks of the Baltimore & Ohio Chicago Terminal Railroad from Baltimore & Ohio Junction, near 75th Street and Oakley Avenue, to the terminal, a distance of 11.2 miles.

3. The Pere Marquette Railroad, which has rights over the tracks of the Baltimore & Ohio Chicago Terminal Railroad from Pere Marquette Junction, near 15th Street and Stewart Avenue, to the terminal, a distance of 0.9 mile.

During the year 1912, an average of 4 suburban and 15 through passenger trains arrived at, and 4 suburban and 15 through passenger trains departed from, the terminal every week day. The total incoming and outgoing passengers handled during 1912 was 883,844.

Union Station

The Union Station, located on the northeast corner of Adams and Canal streets, is shown by fig. 300.

This passenger terminal was opened for traffic April 4, 1881. The building and tracks immediately connected with it are owned by the Union Passenger Station Company, but the approaching main tracks, both from the north and the south, are owned jointly by the following railroad companies, which also use the terminal facilities.

1. The Chicago, Milwaukee & St. Paul Railway, approaching the station from the north and west over tracks owned jointly with the Pittsburgh, Cincinnati, Chicago & St. Louis Railway, from Western Avenue Junction to the terminal, a distance of 3.0 miles.

2. The Pittsburgh, Cincinnati, Chicago & St. Louis Railway (Pan Handle), approaching the station from the north and west over the same tracks as the Chicago, Milwaukee & St. Paul Railway, from Western Avenue Junction to the terminal, a distance of 3.0 miles.

3. The Pittsburgh, Fort Wayne & Chicago Railway, approaching the station from the south

FIG. 301. LA SALLE STREET STATION

over tracks owned jointly with the Chicago & Alton Railroad, from Chicago & Alton Junction, near 21st Street and Stewart Avenue, to the terminal, a distance of 1.8 miles.

4. The Chicago & Alton Railroad, approaching the station from the south over tracks owned jointly with the Pittsburgh, Fort Wayne & Chicago Railway, from Fort Wayne Junction, near 21st Street and Stewart Avenue, to the terminal, a distance of 1.8 miles.

TABLE CLX. SUMMARY OF TRAFFIC AT THE MAIN PASSENGER TERMINALS OF CHICAGO
(Basis of 1912)

Station	Date Opened	Number of Passengers handled during 1912	Average Number of Through Trains each Week Day in 1912		Average Number of Suburban Trains each Week Day in 1912	
			Arrived	Departed	Arrived	Departed
1	2	3	4	5	6	7
Chicago & North Western Station	June 4, 1911	14,582,315	70	71	102	102
Illinois Central Station	April 17, 1893	1,594,542	42	43	..	...
Dearborn Station	May 18, 1885	4,064,457	39	37	28	29
Grand Central Station	Dec. 10, 1890	883,844	15	15	4	4
Union Station	April 4, 1881	7,890,599	72	69	61	61
La Salle Street Station	July 12, 1903	10,847,800	53	53	56	57

5. The Chicago, Burlington & Quincy Railroad, entering the station from the south over tracks owned jointly by the Chicago & Alton Railroad and the Pittsburgh, Fort Wayne & Chicago Railway, from a point near 16th Street and Stewart Avenue to the terminal, a distance of 0.9 miles.

During the year 1912, an average of 61 suburban and 72 through passenger trains arrived at, and 61 suburban and 69 through passenger trains departed from, this station every week day. The total number of incoming and outgoing passengers handled during 1912 was 7,890,599.

La Salle Street Station

The La Salle Street Station, located between La Salle Street and Sherman Street, with main entrance on Van Buren Street, is shown by fig. 301.

The building was opened for traffic July 12, 1903. It is owned jointly by the Chicago, Rock Island & Pacific Railway and the Lake Shore & Michigan Southern Railway, and is occupied largely by the offices of these two roads. The terminal is used for both through and suburban trains, which enter it from the south over tracks owned jointly by the Chicago, Rock Island & Pacific Railway and the Lake Shore & Michigan Southern Railway.

The La Salle Street Station is used as a terminal by the following railroads:

1. The Chicago, Rock Island & Pacific Railway, which enters from the south over tracks owned jointly with the Lake Shore & Michigan Southern Railway, from Englewood to the terminal, a distance of 6.5 miles.

2. The Lake Shore & Michigan Southern Railway, which enters from the south over tracks owned jointly with the Chicago, Rock Island & Pacific Railway, from Englewood to the terminal, a distance of 6.5 miles.

3. The Chicago, Indiana & Southern Railroad, which has rights over the tracks of the Lake Shore & Michigan Southern Railway from Indiana Harbor, Ind., to the terminal, a distance of 19.3 miles.

4. The Chicago & Eastern Illinois Railroad, which has rights over the tracks of the Chicago, Rock Island & Pacific Railway from Auburn Park, near 79th and Wallace streets, to the terminal, a distance of 8.6 miles.*

5. The New York, Chicago & St. Louis Railroad (Nickel Plate), which has rights over the tracks of the Chicago, Rock Island & Pacific Railway from Pullman Junction, near 95th Street and Blackstone Avenue, to the terminal, a distance of 11.4 miles.

During the year 1912, an average of 56 suburban and 53 through passenger trains arrived at, and 57 suburban and 53 through passenger trains departed from, this station every week day. The total number of incoming and outgoing passengers handled during 1912 was 10,847,800.

201.12 Traffic Summary: A summary of the statistical facts with reference to main passenger terminals, as set forth in the preceding section, is presented by table CLX.

201.13 Suburban Passenger Terminals: The significance of the suburban terminals is indicated by the character and extent of the traffic handled through them. The roads operating suburban passenger trains out of Chicago, the outermost station reached by suburban trains, as defined by each road, and the distance between this station and the Chicago passenger terminal, are set forth for the Committee's statistical year, 1912, by table CLXI.

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*Since Aug. 1, 1913, this railroad has used the Dearborn Station

TABLE CLXI. OUTERMOST STATIONS REACHED BY SUBURBAN TRAINS

Railroad	Outermost Suburban Station	No. Miles from Chicago Terminal
Baltimore & Ohio Chicago Terminal R. R.	Chicago Heights, Ill.	30.6
Chicago & Alton R. R.	Joliet, Ill.	37.2
Chicago & Eastern Illinois R. R.	Crete, Ill.	30.4
Chicago & North Western Ry	Barrington, Ill. Waukegan, Ill. West Chicago, Ill.	31.6 35.9 30.0
Chicago & Western Indiana R. R	Dolton, Ill.	16.6
Chicago, Burlington & Quincy R. R	Aurora, Ill.	37.4
Chicago, Milwaukee & St. Paul Ry	Elgin, Ill. Libertyville, Ill. Sheridan Park, Ill.	36.7 35.5 8.0
Chicago, Rock Island & Pacific Ry	Joliet, Ill.	36.7
Grand Trunk Western Ry	Valparaiso, Ind.	55.8
Illinois Central R. R	Matteson, Ill. Blue Island, Ill. South Chicago, Ill.	28.0 18.7 12.6
	Addison, Ill.	24.2
Lake Shore & Michigan Southern Ry	Chesterton, Ind.	41.1
Pittsburgh, Fort Wayne & Chicago Ry	Valparaiso, Ind.	43.6
Wabash Railroad	Manhattan, Ill.	39.9

The number of suburban passengers carried by these roads during the Committee's statistical year, 1912, as disclosed by the number of tickets issued for rides between Chicago and all suburban stations within the limits indicated by the outermost station, is set forth by table CLXII. This number includes tickets from and to Chicago.

TABLE CLXII. PASSENGERS CARRIED BETWEEN CHICAGO AND POINTS WITHIN SUBURBAN LIMITS
(Basis of 1912)

Station and Railroad	Suburban Passengers Carried		Per Cent of Total Suburban Passengers	
	By Railroads	For Station or Group	By Railroads	For Station or Group
1	2	3	4	5
Chicago & North Western Terminal		12,252,160		29.09
Chicago & North Western Ry	12,252,160		29.09	
Central, Randolph St. and Van Buren St. Stations		13,310,629		31.60
Illinois Central R. R	13,301,819		31.58	
Minneapolis, St. Paul & Sault Ste. Marie Ry	8,810		02	
Dearborn Station		2,581,112		6.12
Chesapeake & Ohio Ry. of Indiana	5,795		01	
Chicago & Western Indiana R. R	1,472,345		3.49	
Grand Trunk Western Ry	765,000		1.81	
Wabash Railroad	337,972		.81	
Grand Central Station		257,930		.61
Baltimore & Ohio Chicago Terminal R. R	252,509		.60	
Chicago Great Western R. R	5,450		.01	
Union Station		4,888,860		11.61
Chicago & Alton R. R	154,054		.37	
Chicago, Burlington & Quincy R. R	4,104,556		9.74	
Chicago, Milwaukee & St. Paul Ry.	448,750		1.07	
Pittsburgh, Fort Wayne & Chicago Ry	181,500		.43	
La Salle St. Station		8,828,902		20.97
Chicago & Eastern Illinois R. R	472,777		1.13	
Chicago, Indiana & Southern R. R	53,563		.13	
Chicago, Rock Island & Pacific Ry	4,488,971		10.66	
Lake Shore & Michigan Southern Ry	3,813,591		9.05	
Totals	42,119,593	42,119,593	100.00	100.00

The individual suburban passenger stations in Chicago which handle the largest number of passengers are the Van Buren Street and Randolph Street stations of the Illinois Central Railroad. The Randolph Street Station constitutes the terminal for the suburban trains of this railroad. Practically all of the suburban passenger traffic of the Illinois Central Railroad, bound to or from the downtown business district, is handled by these two stations. During the year 1912, an average of 145 suburban passenger trains arrived at, and 144 departed from, the Randolph Street terminal every week day. During the same year 13,301,819 suburban passengers were handled by the Illinois Central Railroad and most of this traffic was served by these two stations.

A number of different types of suburban passenger stations, varying from mere shelter sheds at outlying points for the accommodation of a few passengers only, to the more pretentious and artistic structures along the "north shore" suburban lines, are illustrated by figs. 302 to 309 inclusive.

201.14 Freight Terminals: The freight houses of the Chicago terminals are of first importance to the daily business life of the city. In 1912, 8,549,630 tons of freight were handled through these freight houses. As nearly all freight handled is carted from and to them, their proximity to the business district is a matter of importance to shippers. That this feature of advantage has not been overlooked by the railroads of Chicago, is made obvious by the map which is presented as fig. 310.

A list of the freight houses in the business district of Chicago is presented as table CLXIII.

FIG. 302. SUBURBAN STATIONS. Station at Stone Avenue, La Grange, Ill., Chicago, Burlington & Quincy Railroad.

FIG. 305. SUBURBAN STATIONS. Station at Indiana Harbor, Ind., Lake Shore & Michigan Southern Railway.

FIG. 303. SUBURBAN STATIONS. Station at East Chicago, Ind., Pittsburgh, Fort Wayne & Chicago Railway.

FIG. 306. SUBURBAN STATIONS. Station at Forest Park, Ill., Chicago Great Western Railroad.

FIG. 304. SUBURBAN STATIONS. Station at Morgan Park, Ill., Chicago, Rock Island & Pacific Railway

FIG. 307. SUBURBAN STATIONS. Station at Flossmoor, Ill., Illinois Central Railroad.

TABLE CLXIII. FREIGHT HOUSES IN THE BUSINESS DISTRICT OF CHICAGO

Map No.*	Owned by	Use
1	Illinois Central R. R	Dock house
2	Illinois Central R. R.	Inbound †
3	Illinois Central R. R.	Fruit house
4	Illinois Central R. R.	Outbound
5	Michigan Central R. R	Inbound
6	Illinois Central R. R.	Dock house
7	Illinois Central R. R	Inbound
8	Michigan Central R. R	Outbound
9	Michigan Central R. R	Inbound
10	Chicago & North Western Ry	Outbound
11	Chicago & North Western Ry	Outbound
12	Chicago & North Western Ry	Inbound
13	Chicago & North Western Ry	Fruit house
14	Chicago, Milwaukee & St. Paul Ry	Outbound
15	Chicago, Milwaukee & St. Paul Ry	Inbound
16	Chicago & North Western Ry	Freight storage
17	Chicago & North Western Ry	Outbound
18	Chicago & North Western Ry	Inbound
19	Pittsburgh, Cincinnati, Chicago & St. Louis Ry	Inbound
20	Chicago, Milwaukee & St. Paul Ry	Inbound
21	Chicago, Milwaukee & St. Paul Ry	Freight offices
22	Chicago, Milwaukee & St. Paul Ry	Outbound
23	Chicago, Milwaukee & St. Paul Ry	Outbound
24	Pittsburgh, Cincinnati, Chicago & St. Louis Ry	Outbound
25	Chicago, Milwaukee & St. Paul Ry	Dock house
26	Pittsburgh, Fort Wayne & Chicago Ry	Inbound
27	Pittsburgh, Fort Wayne & Chicago Ry	Inbound
28	Pittsburgh, Fort Wayne & Chicago Ry	Outbound
29	Chicago & Alton R. R	Freight office
30	Chicago & Alton R. R	In and out ‡
31	Chicago & Alton R. R	Inbound
32	Chicago & Alton R. R	Outbound
33	Pittsburgh, Fort Wayne & Chicago Ry	In and out
34	Chicago, Burlington & Quincy R. R	Freight office
35	Chicago, Burlington & Quincy R. R	Outbound
36	Chicago, Burlington & Quincy R. R	Outbound
37	Chicago, Burlington & Quincy R. R	Inbound
38	Pittsburgh, Fort Wayne & Chicago Ry	Inbound
39	Chicago Great Western R. R	In and out
40	Pere Marquette R. R	In and out
41	Baltimore & Ohio R. R	Inbound
42	Baltimore & Ohio R. R	Outbound
43	Chicago, Rock Island & Pacific Ry	Inbound
44	Chicago, Rock Island & Pacific Ry	Outbound
45	Lake Shore & Michigan Southern Ry	Outbound §
46	Lake Shore & Michigan Southern Ry	Inbound ¶
47	Wabash R. R	Outbound
48	Chicago, Indianapolis & Louisville Ry	Out and in
49	Grand Trunk Western Ry	Outbound
50	Chicago & Eastern Illinois R. R	Outbound
51	New York, Chicago & St. Louis R. R	Inbound
52	New York, Chicago & St. Louis R. R	Outbound
53	Chicago, Rock Island & Pacific Ry	Outbound
54	Chicago, Rock Island & Pacific Ry	Outbound
55	Chicago & Eastern Illinois R. R	Offices
56	Chicago, Rock Island & Pacific Ry	Dock house
57	Chicago & Eastern Illinois R. R	Inbound
58	Wabash R. R	Inbound
59	Grand Trunk Western Ry	Inbound
60	Atchison, Topeka & Santa Fe Ry	Outbound
61	Chicago, Rock Island & Pacific Ry	Dock house
62	Chicago & Erie R. R	In and out
63	Atchison, Topeka & Santa Fe Ry	Inbound
64	Chicago, Burlington & Quincy R. R	In and out
65	Pittsburgh, Fort Wayne & Chicago Ry	Transfer
66	Chicago, Burlington & Quincy R. R.	Freight storage
67	Baltimore & Ohio Chicago Terminal R. R	Outbound •
68	Chicago & North Western Ry	Inbound
69	Chicago, Burlington & Quincy R. R	Outbound

* This number corresponds to the numbers shown on the map, fig. 310.

† Leased by M. St. P. & S. S. M. Ry. which now (1914) uses its own terminal at 12th and Canal streets.

‡ Handles C. & O. Ry. freight exclusively.

§ Also handles C. I. & S. R. R. freight.

¶ Leased by C. M. & St. P. Ry.

FIG. 308. SUBURBAN STATIONS. Station at Rogers Park, Chicago & North Western Railway.

FIG. 309. SUBURBAN STATIONS. Station at Park Ridge, Ill., Chicago & North Western Railway.

All the principal freight houses of the city are within one and a quarter miles of the postoffice. The few outlying freight houses may be considered as auxiliary facilities established for the greater convenience of secondary business centers. Examples of this type may be found in the freight stations of the Pittsburgh, Fort Wayne & Chicago Railway at Grand Crossing and the Lake Shore & Michigan Southern Railway at South Chicago, and in the freight station of the Illinois Central Railroad at Kensington. Many of these outlying freight stations handle a large volume of business and serve large business districts. There are also a number of important freight transfer stations, such as the Wood Street Station of the Chicago & North Western Railway, which has a capacity of approximately 300 cars daily, and the Corwith Station of the Atchison, Topeka & Santa Fe Railway.

The typical railroad freight house of Chicago is a single story structure served by railroad tracks and team ways. The grouping of such stations concentrates activities and in some cases gives rise to a congestion of street traffic. The territory immediately to the south of the Dearborn and La Salle stations, extending to about 16th Street, is occupied either by freight tracks or by buildings for the care of freight service. A constant procession of teams which deliver and receive freight at the freight houses is to be seen in this district. Similar conditions exist along the tracks in Kinzie Street, from Ada Street east to Lake Michigan, along those from the Union Station south to 16th Street, and in the South Water Street Yard of the Illinois Central Railroad.

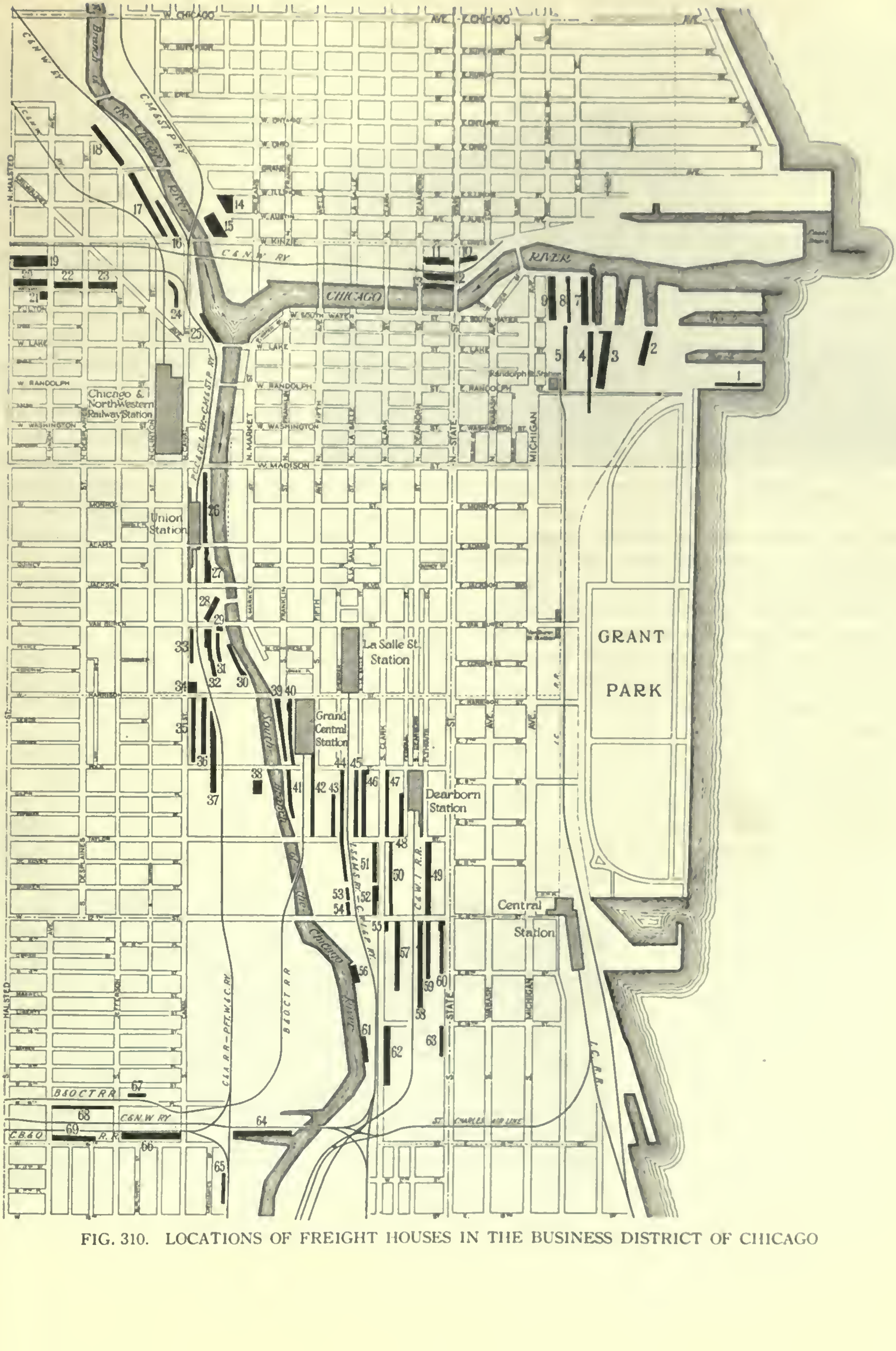

FIG. 310. LOCATIONS OF FREIGHT HOUSES IN THE BUSINESS DISTRICT OF CHICAGO

FIG. 311. FREIGHT HOUSES. Freight House of the Illinois Central Railroad at the South Water Street Yard, Chicago.

The four districts just mentioned contain 65 freight houses, not including several small buildings used for freight offices. The recently completed* freight terminal of the Minneapolis, St. Paul & Sault Ste. Marie Railway (Soo Line) at 12th and Canal streets furnishes an interesting example of a modern freight handling plant.

The principal freight houses in the downtown business section have direct connections with the bores of the Chicago Tunnel Company, which run about 40 feet beneath the street level under practically all of the streets in the district. These bores, some 60 miles in extent, provide direct connection between the freight houses and many of the large business houses in the district served. Views of freight houses and of the activities about them are presented as figs. 311 to 322, inclusive.

FIG. 312. FREIGHT HOUSES. In-freight House of the Chicago, Rock Island & Pacific Railway, at Sherman and Taylor Streets, Chicago.

A lighterage service, supplemental to the railroad service, is conducted along the Chicago River and its branches. Convenient stations are provided for this service and regular trips are made by the lighters for the collection and distribution of freight. Types of vessels used in this service are shown by the illustrations presented as figs. 323 and 325. The Erie car transfer boat illustrated is used in a new water transfer service recently inaugurated. In this service convenient collecting and loading points have been established. Freight cars, either loaded or empty, are transferred on barges from one location to another as conditions may demand.

201.15 Team Yards: Team yards consist of team tracks upon which cars are placed to be loaded or unloaded. Cars so placed are used for what are generally termed "carload" shipments, to which the carload or wholesale freight rate applies. This rate is less than the rate applying to less-than-carload shipments, which are loaded and unloaded through freight houses. In the case of carload shipments handled on team tracks the work of loading or unloading is performed by the consignor or consignee; in the case of less-than-carload shipments, or shipments handled through freight houses, this work is performed by the railroads.

In the city of Chicago there are 62.97 miles of team tracks, amounting to 2.2 per cent of the total mileage of track of all kinds. Some

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*Opened April 1, 1914.

of the team yards in Chicago are of considerable size as, for example, the Grand Avenue Yard of the Chicago & North Western Railway, which has 5.5 miles of track, the 14th Street Yard of the Baltimore & Ohio Chicago Terminal Railroad, which has 4.7 miles, and the Union Street yard of the Chicago, Milwaukee & St. Paul Railway, which has 7.5 miles.

Various scenes in connection with the work about team tracks are shown by figs. 324 and 326 to 328, inclusive.

FIG. 313. FREIGHT HOUSES. Freight House of the Minneapolis, St. Paul & Sault Ste. Marie Railway, at Canal and 12th Streets, Chicago.

201.16 Freight Yards: Freight yards serve many different purposes. Some are designed, in combination with team tracks, for convenience in loading and unloading cars in certain defined industrial centers, and some take the form of large switching yards, the purpose of which is to facilitate the receiving, classifying and forwarding of freight cars. For example, a train approaching Chicago may contain cars destined to various parts of the city or to different parts of the country. Such a train is delivered to a receiving yard from which the cars are transferred to the classification yard, where they are sorted to form new groups, the individual cars of which may be billed for delivery to different railroads or to different parts of the city upon the same railroad. At intervals, cars re-grouped by such a process move on to their destination. Similarly, cars leaving the city are brought from many different directions to the classification yard and there combined into trains. The movements of cars between the classification yards and the city are commonly referred to as transfer or switching movements. Those movements which take place beyond the classification yard are normally road movements.

A number of Chicago's freight yards cover 160 acres or more of land each, and one occupies a tract of 240 acres. In the Union Stock Yards, which cover a square mile of territory, railroad tracks form a network serving this industry.

Conditions which have prompted the construction of freight houses as near the business center as possible have also influenced the selection of locations for switching yards, but as difficulties in finding space within the city have increased, more remote locations have been chosen.

The recently established yards of the Chicago, Milwaukee & St. Paul Railway at Mannheim, Ill., the extensions to the Proviso

FIG. 314. FREIGHT HOUSES. Loading Platform of the Freight House of the Michigan Central Railroad, at the South Water Street Yard, Chicago.

FIG. 315. FREIGHT HOUSES. Freight House of the Monon Railway at Federal and Taylor Streets, Chicago.

Yard of the Chicago & North Western Railway, and the Wildwood Yard of the Illinois Central Railroad, are examples of the more extensive outlying freight yards.

Within the city of Chicago there are 67 principal and 51 minor railroad freight switching yards, while outside of the city limits, but within the Area of Investigation, there are 40 principal and 19 minor yards. By "principal yard" is meant one which, because of its size or importance, has a well defined name. A "minor yard" embraces small groups of tracks used for teaming, car storage or other purposes, and usually has no well defined name.

The largest general railroad yard within the Area of Investigation is the 40th Avenue Yard of the Chicago & North Western Railway, which has about 88 miles of track. The largest switching yard is the Clearing Yard of the Chicago Union Transfer Railway at Clearing, Ill. A considerable number of the more important classification yards, including those of the Chicago & Eastern Illinois Railroad at Dolton, Ill., the Chicago, Indiana & Southern Railroad at Gibson, Ind., the Chicago Union Transfer Railway at Clearing, Ill., and the Chicago, Milwaukee & St. Paul Railway at Mannheim, Ill., are of the type known as "hump" yards, in which the classification of cars is effected by gravity.

The principal railroad yards and most of the minor yards in the city of Chicago, between Belmont Avenue on the north and 103d Street on the south, are enumerated in table CLXIV. This list contains the names of the principal railroad yards shown on the maps, figs. 95 to 245, already presented (section 201.02).

Views of typical yards in the Area of Investigation are presented as figs. 329 to 336, inclusive.

The locations of the yards listed in table CLXIV are shown on the terminal map presented as fig. 337.

201.17 Yards for Miscellaneous Purposes: In addition to freight yards, there are within the Area of Investigation numerous yards used for miscellaneous purposes, such as scrap yards, repair yards, terminal yards and wheel yards. Views of such are presented as figs. 338 to 343, inclusive.

FIG. 316. FREIGHT HOUSES. Freight House of the Pittsburgh, Cincinnati, Chicago & St. Louis Railway at Morgan and Kinzie Streets, Chicago.

FIG. 317. FREIGHT HOUSES. Gantry Crane at the Wood Street Yard Transfer Station of the Chicago & North Western Railway, 14th Place and Oakley Avenue, Chicago.

FIG. 320. FREIGHT HOUSES. Freight Station of the Pittsburgh, Fort Wayne & Chicago Railway at Grand Crossing, near 76th Street, Chicago.

FIG. 318. FREIGHT HOUSES. Freight Offices of the Chicago, Milwaukee & St. Paul Railway at Healy Station, Chicago.

FIG. 321. FREIGHT HOUSES. Freight Station of the Lake Shore & Michigan Southern Railway at Grand Crossing, near 76th Street, Chicago.

FIG. 319. FREIGHT HOUSES. Freight Transfer Station of the Chicago & North Western Railway at 14th Place and Oakley Avenue, Chicago.

FIG. 322. FREIGHT HOUSES. Freight Station of the Chicago & Western Indiana Railroad, in the Englewood Yard at 66th Street, Chicago.

FIG. 323. LIGHTERAGE SERVICE. Lighter of the Merchants' Lighterage Co., used on the Chicago River and its Branches.

FIG. 324. TEAM YARDS. Robey Street Team Yard of the Pittsburgh, Cincinnati, Chicago & St. Louis Railway.

FIG. 325 LIGHTERAGE SERVICE. Car Float of the Erie Railroad at Erie Street and the North Branch of the Chicago River.

FIG. 326. TEAM YARDS. North Avenue Team Yard of the Chicago & North Western Railway.

FIG. 327. TEAM YARDS. Team Yard of the Chicago & Western Indiana Railroad at 64th and Wallace Streets.

FIG. 328. TEAM YARDS. Team Yard of the Wabash Railroad, South of the Twelfth Street Viaduct.

TABLE CLXIV. LIST OF FREIGHT YARDS IN CHICAGO, BETWEEN BELMONT AVENUE AND 103D STREET

Railroad	Name of Yard or Vicinity	Section Map Index No.
Atchison, Topeka & Santa Fe Ry	*12th Street	45–32
Atchison, Topeka & Santa Fe Ry	18th Street	45
Atchison, Topeka & Santa Fe Ry	*Elevator	50
Atchison, Topeka & Santa Fe Ry	Corwith	70
Baltimore & Ohio R. R	South Chicago	127
Baltimore & Ohio Chicago Terminal R. R	*Grand Central Station	32
Baltimore & Ohio Chicago Terminal R. R	Empire Slip	32
Baltimore & Ohio Chicago Terminal R. R	14th Street Team	45
Baltimore & Ohio Chicago Terminal R. R	Morgan Street Team	44
Baltimore & Ohio Chicago Terminal R. R	Robey Street	43
Baltimore & Ohio Chicago Terminal R. R	Homan Avenue	36
Baltimore & Ohio Chicago Terminal R. R	48th Avenue	37
Chicago & Alton R. R	*Union Station	32
Chicago & Alton R. R	Halsted Street	49
Chicago & Alton R. R	Brighton Park	58
Chicago & Eastern Illinois R. R	35th Street	61
Chicago & Eastern Illinois R. R	Oakdale	131
Chicago & Erie R. R	51st Street	79
Chicago & Erie R. R	87th Street	131
Chicago & North Western Ry	Madison Street Terminal	29
Chicago & North Western Ry	*State Street District	29–30
Chicago & North Western Ry	Wells Street	29
Chicago & North Western Ry	Western Avenue	26
Chicago & North Western Ry	40th Avenue	24
Chicago & North Western Ry	*Grand Avenue District	29
Chicago & North Western Ry	Erie Street	29
Chicago & North Western Ry	*Deering	3
Chicago & North Western Ry	Diversey Avenue Team	3
Chicago & North Western Ry	North Avenue Team	17
Chicago & North Western Ry	Wood Street	43
Chicago & Western Indiana R. R	*Dearborn Station	32
Chicago & Western Indiana R. R	51st Street	79
Chicago & Western Indiana R. R	Englewood Team	98
Chicago & Western Indiana R. R	Oakdale	131
Chicago & Western Indiana R. R. (The Belt Ry. of Chicago)	West Chicago	21
Chicago & Western Indiana R. R. (The Belt Ry. of Chicago)	West 12th Street	40
Chicago & Western Indiana R. R. (The Belt Ry. of Chicago)	Hawthorne	53
Chicago & Western Indiana R. R. (The Belt Ry. of Chicago)	Le Moyne	71
Chicago & Western Indiana R. R. (The Belt Ry. of Chicago)	Hayford	111
Chicago & Western Indiana R. R. (The Belt Ry. of Chicago)	Rockwell Street	110
Chicago & Western Indiana R. R. (The Belt Ry. of Chicago)	83d Street	120
Chicago & Western Indiana R. R. (The Belt Ry. of Chicago)	Burnside	129
Chicago & Western Indiana R. R. (The Belt Ry. of Chicago)	South Chicago	127–128
Chicago, Burlington & Quincy R. R	*Union Station	32
Chicago, Burlington & Quincy R. R	12th Street	32
Chicago, Burlington & Quincy R. R	*16th Street	45
Chicago, Burlington & Quincy R. R	Western Avenue	43
Chicago, Burlington & Quincy R. R	*Lumber District	49–50
Chicago, Burlington & Quincy R. R	Hawthorne	54
Chicago Great Western R. R	48th Avenue	38
Chicago Junction Ry	Kenwood Team	64
Chicago Junction Ry	Halsted Street	67
Chicago Junction Ry	Center Avenue	67
Chicago Junction Ry	Loomis Street	67
Chicago Junction Ry	Ashland Avenue	68
Chicago Junction Ry	*Central Mfg. District	60
Chicago, Indianapolis & Louisville Ry	Taylor Street	32
Chicago, Milwaukee & St. Paul Ry	*Union Station	32
Chicago, Milwaukee & St. Paul Ry	Union Street	29
Chicago, Milwaukee & St. Paul Ry	Western Avenue	26
Chicago, Milwaukee & St. Paul Ry	Galewood	8
Chicago, Milwaukee & St. Paul Ry	Division Street	17
Chicago, Milwaukee & St. Paul Ry	North Avenue	13
Chicago River & Indiana R. R	Leavitt Street	68
Chicago River & Indiana R. R	Dock House	50
Chicago, Rock Island & Pacific Ry	*La Salle Street Station	32
Chicago, Rock Island & Pacific Ry	43d Street	66
Chicago, Rock Island & Pacific Ry	47th Street	79
Chicago, Rock Island & Pacific Ry	Gresham	132
Chicago, Rock Island & Pacific Ry	63d Street Team	98
Chicago, Rock Island & Pacific Ry	South Chicago	128
Chicago Short Line Ry	*Iroquois Iron Works	126
Elgin, Joliet & Eastern Ry	*North Works	13
Elgin, Joliet & Eastern Ry	Bridgeport	60
Elgin, Joliet & Eastern Ry	*South Works	125–126
Elgin, Joliet & Eastern Ry	98th Street	150
Grand Trunk Western Ry	Elsdon	75
Grand Trunk Western Ry	Hayford	111
Illinois Central R. R	Randolph Street	30
Illinois Central R. R	12th Street	31
Illinois Central R. R	Fordham	122–129
Illinois Central R. R	*Burnside shops	145
Illinois Central R. R	104th Street	145
Illinois Northern Ry	McCormick	51
Illinois Northern Ry	33d Street	57
Lake Shore & Michigan Southern Ry	*La Salle Street Station	32
Lake Shore & Michigan Southern Ry	43d Street	66
Lake Shore & Michigan Southern Ry	Englewood	99
Lake Shore & Michigan Southern Ry	South Chicago	127
Michigan Central R. R	Randolph Street	30
Michigan Central R. R	16th Street	46
New York, Chicago & St. Louis R. R	Stony Island	129
Pere Marquette R. R	Tracy	141

* Indicates a vicinity or district rather than a specific yard name.

TABLE CLXIV (Continued). LIST OF FREIGHT YARDS IN CHICAGO, BETWEEN BELMONT AVENUE AND 103D STREET

Railroad	Name of Yard or Vicinity	Section Map Index No
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	*Union Station	32
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	Ada Street	28
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	Robey Street Team	27
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	16th Street	42
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	59th Street	87
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	*Washington Heights	143
Pittsburgh, Fort Wayne & Chicago Ry	*Union Station	32
Pittsburgh, Fort Wayne & Chicago Ry	14th Street	45
Pittsburgh, Fort Wayne & Chicago Ry	18th Street	45
Pittsburgh, Fort Wayne & Chicago Ry	Garfield Boulevard	79
Pittsburgh, Fort Wayne & Chicago Ry	Englewood Team	98-99
Pittsburgh, Fort Wayne & Chicago Ry	Grand Crossing	105
Pullman Railroad	*Pullman Junction	146
Wabash Railroad	47th Street	66
Wabash Railroad	Ullman Street	60
Wabash Railroad	Landers	110
Wabash Railroad	Chandler	108

* Indicates a vicinity or district rather than a specific yard name.

FIG. 329. FREIGHT YARDS. Dolton Yard of the Chicago & Eastern Illinois Railroad.

FIG. 330. FREIGHT YARDS. Jackson Street Yard of the Illinois Central Railroad.

FIG. 331. FREIGHT YARDS. Galewood Yard of the Chicago, Milwaukee & St. Paul Railway.

FIG. 332. FREIGHT YARDS. South Water Street Yard of the Illinois Central Railroad.

FIG. 333. FREIGHT YARDS. Proviso Yard of the Chicago & North Western Railway.

FIG. 334. FREIGHT YARDS. Clearing Yard of the Chicago Union Transfer Railway.

(Since the close of the Committee's Statistical Year, 1912, this yard has been purchased by the Chicago & Western Indiana Railroad and leased to the Belt Railway of Chicago.)

FIG. 335. FREIGHT YARDS. Argo Yard of the Indiana Harbor Belt Railroad.

FIG. 336. FREIGHT YARDS. Hawthorne Yard of the Chicago, Burlington & Quincy Railroad.

FIG. 337. LOCATIONS OF RAILROAD YARDS IN THE AREA OF INVESTIGATION

201.18 Locomotive Terminals: Locomotive terminals are located at many points both within the city and beyond the city limits. At these terminals, facilities for the care of steam locomotives are provided. A list of all locomotive engine houses within the Area of Investigation is presented as table CLXV.

TABLE CLXV. LOCOMOTIVE ENGINE HOUSES WITHIN THE AREA OF INVESTIGATION

Engine House Number*	Railroad		Number of Stalls
1	Atchison, Topeka & Santa Fe Ry		14
2	Atchison, Topeka & Santa Fe Ry		31
3	Baltimore & Ohio R. R		27
4	Baltimore & Ohio Chicago Terminal R. R		18
5	Baltimore & Ohio Chicago Terminal R. R		15
6	Baltimore & Ohio Chicago Terminal R. R		8
7	Calumet, Hammond & Southeastern R. R		1
8	Chesapeake & Ohio Ry. of Indiana		4
9	Chicago & Alton R. R		22
10	Chicago & Eastern Illinois R. R		20
11	Chicago & Erie R. R		10
12	Chicago & Illinois Western R. R		2
13	Chicago & North Western Ry		29
14	Chicago & North Western Ry		24
15	Chicago & North Western Ry		36
16	Chicago & North Western Ry		39
17	Chicago & North Western Ry		58
18	Chicago & North Western Ry		12
19	Chicago & North Western Ry		9
20	Chicago & Western Indiana R. R		51
21	Chicago & Western Indiana R. R. and the Belt Ry. of Chicago		22
22	Chicago, Burlington & Quincy R. R		15
23	Chicago, Burlington & Quincy R. R		38
24	Chicago, Burlington & Quincy R. R		3
25	Chicago Great Western R. R		15
26	Chicago, Indiana & Southern R. R		25
27	Chicago, Indianapolis & Louisville Ry		10
28	Chicago Junction Ry		25
29	Chicago, Milwaukee & St. Paul Ry		35
30	Chicago, Milwaukee & St. Paul Ry		36
31	Chicago, Milwaukee & St. Paul Ry		4
32	Chicago, Rock Island & Pacifio Ry		38
33	Chicago, Rock Island & Pacific Ry		39
34	Chicago, Rock Island & Pacific Ry		29
35	Chicago, Rock Island & Pacific Ry		1
36	Chicago Short Line Ry		4
37	Chicago Union Transfer Ry		10
38	Chicago, West Pullman & Southern R. R		4
39	Chicago, West Pullman & Southern R. R		2
40	Elgin, Joliet & Eastern Ry		1
41	Elgin, Joliet & Eastern Ry		8
42	Elgin, Joliet & Eastern Ry		5
43	Elgin, Joliet & Eastern Ry		20
44	Grand Trunk Western Ry		25
45	Grand Trunk Western Ry		3
46	Illinois Central R. R		19
47	Illinois Central R. R		23
48	Illinois Central R. R		38
49	Illinois Central R. R		28
50	Illinois Northern Ry		6
51	Indiana Harbor Belt R. R		3
52	Lake Shore & Michigan Southern Ry		19
53	Manufacturers' Junction Ry		5
54	Michigan Central R. R		10
55	Michigan Central R. R		6
56	Minneapolis, St. Paul & Sault Ste. Marie Ry		12
57	New York, Chicago & St. Louis R. R		16
58	Pere Marquette R. R		12
59	Pittsburgh, Cincinnati, Chicago & St. Louis Ry		16
60	Pittsburgh, Cincinnati, Chicago & St. Louis Ry		2
61	Pittsburgh, Fort Wayne & Chicago Ry		15
62	Pittsburgh, Fort Wayne & Chicago Ry		10
63	Pullman Railroad		10
64	Wabash Railroad		20
65	Standard Oil Co		12
	Total in Chicago	46	891
	Total in Zone B	19	238
	Grand total	65	1,129

* Numbers in left-hand column refer to numbers shown on map, fig. 344. All engine houses in Chicago are of brick except Nos. 7, 40, 42 and 60.

A map showing the locations of all locomotive engine houses within the Area of Investigation is presented as fig. 344.

Locomotive terminals have facilities for making necessary light repairs to locomotives, as well as for the handling of fuel, water, ash and cinders. The selection of locations for such terminals has been dependent generally upon locations of freight and passenger terminals, the object being to locate locomotive terminals as near as possible to the freight and passenger terminals of the road. In earlier days, the engine terminals served for both freight and passenger locomotives. As traffic increased and old terminals proved inadequate, new terminals were established farther out to provide facilities for the care of locomotives engaged in freight service. The older terminals, located nearer the passenger stations, were retained for the care of locomotives used in passenger service.

Examples of terminals used principally or exclusively for passenger locomotives include the 12th Street plant of the Chicago, Burlington & Quincy Railroad, at 12th and Canal streets, the Empire Slip plant of the Baltimore & Ohio Chicago Terminal Railroad, at 12th Street and the Chicago River, the 14th Street Yard plant of the Pittsburgh, Fort Wayne & Chicago Railway, at 15th Street and Stewart Avenue, and the 51st Street Yard plant of the Chicago & Western Indiana Railroad, at 49th and Butler streets. The last named plant handles more than 100 locomotives daily.

Among the larger terminals used exclusively for freight locomotives may be mentioned the 83d Street Yard plant of the Belt Railway of Chicago, at 83d Street and Vincennes Avenue, the Godfrey Yard plant of the Chicago, Milwaukee & St. Paul Railway, at Mannheim, Ill., and the Kirk Yard plant of the Elgin, Joliet & Eastern Railway, at Gary, Ind. The terminal of the Belt Railway of Chicago handles approximately 100 locomotives daily.

Two extensive plants for the care of both freight and passenger locomotives are the 40th Avenue plant of the Chicago & North Western Railway, at Cicero Avenue and Kinzie Street, and the Burnside shops of the Illinois Central Railroad, at 95th Street and Cottage Grove Avenue. These are the largest locomotive terminals within the Area of Investigation.

Other extensive locomotive terminals include the plant of the Illinois Central Railroad at 27th Street and Lake Michigan, that of the Chicago, Burlington & Quincy Railroad at Western Avenue

FIG. 338. MISCELLANEOUS YARDS. Wheel Yard of the Lake Shore & Michigan Southern Railway at 63d Street and Michigan Avenue.

FIG. 339. MISCELLANEOUS YARDS. Scrap Yard of the Atchison, Topeka & Santa Fe Railway at Corwith.

FIG. 340. MISCELLANEOUS YARDS. Passenger Terminal Yard of Dearborn Station.

FIG. 341. MISCELLANEOUS YARDS. "Hump" or Gravity Yard of the Chicago, Indiana & Southern Railroad at Gibson, Ind.

FIG. 342. MISCELLANEOUS YARDS. Freight Car Repair Yard of the Chicago & North Western Railway at the 40th Avenue Yard.

FIG. 343. MISCELLANEOUS YARDS. General View of Freight Car Repair Yard of the Chicago & North Western Railway at the 40th Avenue Yard.

FIG. 344. LOCATIONS OF LOCOMOTIVE ENGINE HOUSES IN THE AREA OF INVESTIGATION

FIG. 345. LOCOMOTIVE TERMINALS. Landers Engine House of the Wabash Railroad.

and 16th Street, that of the Chicago & North Western Railway at Chicago Avenue and Halsted Street, that of the Chicago, Milwaukee & St. Paul Railway at the Galewood Yard near Narragansett and Armitage avenues, that of the Chicago Junction Railway at 42d and Robey streets, that of the Chicago, Indiana & Southern Railroad at Gibson, Ind., that of the Chicago & Eastern Illinois Railroad, at Dolton, Ill., and that of the Lake Shore & Michigan Southern Railway at 63d Street and Indiana Avenue.

The largest single roundhouse within the city of Chicago is that of the Chicago & Western Indiana Railroad at 49th and Butler streets. This building has 51 stalls, and the terminal is equipped with a modern coaling station, power plant, water station and ash handling plant. Cinders are handled by means of locomotive cranes, and most of the coaling is done by similar means. This terminal handles more than 100 passenger locomotives daily, including those of the Chicago & Western Indiana Railroad, the Chicago & Erie Railroad, the Chesapeake & Ohio Railway of Indiana, the Chicago, Indianapolis & Louisville Railway, the Chicago & Eastern Illinois Railroad and the Wabash Railroad.

FIG. 346. LOCOMOTIVE TERMINALS. Glenn Yard Locomotive Terminal of the Chicago & Alton Railroad.

The various buildings and facilities of all recently constructed locomotive terminals in the Chicago District are of permanent construction. The engine houses are either of concrete or of brick, and many of the coaling stations and other buildings are of the same materials. Most of the turn-tables are of steel plate girder construction, and they are usually equipped with electric tractors. The lengths of the turn-tables vary from 50 to 90 feet, the majority approximating a length of 75 feet. Turn-table pits usually have concrete walls and brick or concrete paving. Views of locomotive terminals within the Area of Investigation are shown as figs. 345 to 352, inclusive.

Coaling stations are of various types of construction. Some consist of simple platforms from which the coal is shoveled by hand into the locomotive tenders. Others consist of elaborate mechanically operated stations of high grade steel and concrete construction. The largest coaling stations within the Area of Investigation are the two at the 40th Avenue Yard of the Chicago & North Western Railway, each of which has a storage capacity of 1,600 tons. These stations are of wooden construction, with inclined trestle approaches up which cars of coal are pushed by locomotives. Mechanically operated stations are of two principal types, those with a number of buckets running on a continuous chain and those with a Holman or single bucket which is elevated to the top of the storage bins and allowed to dump its contents therein. Examples of the chain bucket type are to be found in the Corwith Yard chute of the Atchison, Topeka & Santa Fe Railway and the 27th Street plant of the Illinois Central Railroad. Examples of typical coaling stations within the Area of Investigation are illustrated elsewhere (section 213.090).

All steam railroads in the Chicago District were requested by the Committee to furnish information regarding locomotive terminal facilities,

FIG. 347. LOCOMOTIVE TERMINALS. Locomotives awaiting Repairs in 40th Avenue Yard of the Chicago & North Western Railway.

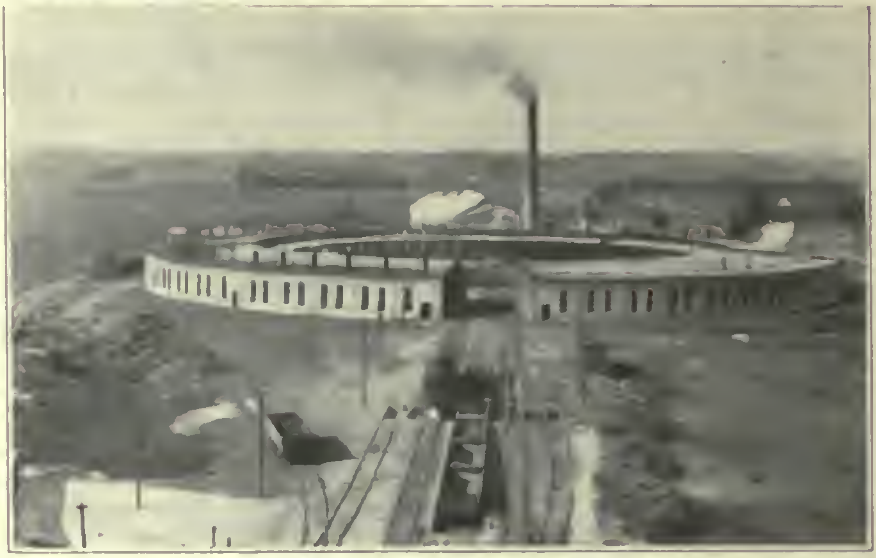

FIG. 348. LOCOMOTIVE TERMINALS. Proviso Engine House of the Chicago & North Western Railway.

FIG. 349. LOCOMOTIVE TERMINALS. Engine House of the Illinois Northern Railway at 26th Street and Blue Island Avenue.

FIG. 350. LOCOMOTIVE TERMINALS. Engine House of the Chicago Great Western Railroad at 46th Avenue and the Baltimore & Ohio Chicago Terminal Railroad.

FIG. 351. LOCOMOTIVE TERMINALS. Engine House of the Chicago, Milwaukee & St. Paul Railway at the Western Avenue Yard.

FIG. 352. LOCOMOTIVE TERMINALS. Robey Street Engine House of the Chicago Junction Railway.

including engine houses, ash-pits, coaling stations, turn-tables, shop buildings, water stations and power stations. This information was furnished on a special form ("Form F") supplied by the Committee. A copy of this form, filled out to show a typical report as submitted by a railroad, is presented as fig. 353.

The information supplied on "Form F" (fig. 353) was summarized as shown by table CLXVI, which refers to structures within the city limits of Chicago.

Water tanks are usually of the familiar wooden tub type either on steel or on wooden frames. A few steel tanks are used, such as those in the Corwith Yard of the Atchison, Topeka & Santa Fe Railway and in the 51st Street Yard of the Chicago & Western Indiana Railroad. These tanks are of various sizes, the largest having

THE CHICAGO ASSOCIATION OF COMMERCE
COMMITTEE OF INVESTIGATION ON SMOKE ABATEMENT
AND ELECTRIFICATION OF RAILWAY TERMINALS
122 MICHIGAN BOULEVARD, CHICAGO.

CHICAGO TERMINAL
STATEMENT OF BUILDINGS
FORM (F)

Sheet No. 1 of 1 Sheets
Chicago & Alton R R. Railway
Division Northern
Between Van Buren St and Albany St.
Office of Ch. Engr. Date June 1912

1. The object of this inquiry is to obtain a list of existing BUILDINGS which would be eliminated or require modification on account of electrification
2. Include all buildings of the classes specified below and which are located within the ZONE of investigation as defined on Official Map of Chicago and Vicinity.
3. In case of JOINT buildings the company maintaining to report.
4. Make entries in India ink.

Locomotive Coaling Stations	Location	Brighton Park				
	Kind	Continuous Bucket				
	Storage Capacity tons	70 tons				
	Approx. Ave. Consumption Coal per 24 hours	325 tons				
Locomotive Water Stations	Location	Chicago, Harrison St.	Chicago, Halsted St.	Chicago, Quarry St.	Brighton Park	
	Source of supply	City Main	City Main	City Main	City Main	
	Size & kind pump house					
	Capacity & kind pumps					
	Capacity & kind tanks				Wood, 44000 Gals.	
	No. & size water cranes	One 8 in.	One 8 in.	One 8 in.	One 10 in.	
	Approx. Ave. Consumption Water per 24 hours	100,000 Gals.	100,000 Gals.	100,000 Gals.	1,200,000 Gals.	
Locomotive Ash pits	Location	Brighton Park				
	Length and kind	2 - 140' Concrete with Ash Hoist				
Engine Houses	Location	Brighton Park				
	Size and kind	22 Stalls, brick				
	No. & length of stalls	11-60', 8-70' and 3-80' long				
	Part used for repair shop	3 Stalls used for engine and boiler room				
Turntables	Location	Brighton Park				
	Length and kind	80 ft. deck, steel with tractor				
	Location	Brighton Park				
	Size & kind erecting shops					
Attached	No. pits					
Shops	Size & kind machine shops	15' x 23', brick				
Running	Size & kind boiler shops					
Repairs	Size & kind tender shops					
For	Size & kind blacksm. shops	15' x 23', brick				
Terminal	Size & kind					
Operation	Size & kind					
	Size & kind					
	Size & kind					
Transfer Tables	Location					
	Length & kind table	None				
	Length of pit					
Electric Light and Power Stations	Location	Brighton Park				
	Power used for	Lighting, hoisting coal, pumping air, heating coaches, charging batteries, operating turntable & heating roundhouse				
	Boiler H.P.	3-80 H.P. boilers				
	Size & kind building	In roundhouse, noted above				
Gas Plants	Location					
	Capacity & kind gas	None				
	Size & kind building					
	Capacity tanks					

FIG. 353. "FORM F." STATEMENT REGARDING LOCOMOTIVE TERMINAL FACILITIES, CHICAGO TERMINALS

a capacity of 200,000 gallons. A considerable number of tanks of less than 50,000 gallons capacity are in use.

Locomotive terminals are commonly supplied with numerous other facilities, depending upon the nature and extent of the service to be performed. Where facilities for repairs to both locomotives and cars are required, the equipment is extensive, as at the Burnside shops of the Illinois Central Railroad and at the 40th Avenue shops of the Chicago & North Western Railway. In such plants, large buildings for shops of various kinds and much heavy machinery are required.

201.19 Coach Yards: For the care of passenger equipment many yards with cleaning and repair facilities are provided. The locations of the principal steam railroad coach yards in the Chicago District are shown by the map presented as fig. 354.

These coach yards are usually located near the passenger terminals. Examples are to be found in the 12th Street Yard of the Illinois Central Railroad, located immediately east of the Central passenger station; in the Empire Slip Yard of the Baltimore & Ohio Chicago Terminal Railroad, located less than one-half mile south of Grand Central Station; and in the Erie Street Yard of the Chicago & North Western Railway, located about one mile north of the Madison Street terminal. The coach yards of the Pittsburgh, Fort Wayne & Chicago Railway and the Atchison, Topeka & Santa Fe Railway are also within convenient distance of their respective passenger terminals. In cases in which a suitable location could not be secured near the passenger station, coach yards have been established at considerable distances therefrom, as in the case of the Lake Shore & Michigan Southern Railway,

TABLE CLXVI. SUMMARY OF STATISTICAL FACTS RELATING TO LOCOMOTIVE TERMINAL FACILITIES. ZONE A
(Basis of 1912)

Railroad	Coaling Stations			Water Stations								Ash-Pits	Engine Houses				Turn-tables
	No.	Storage Cap. Tons	Coal Used in 24 Hr. Tons	No.	Water Used in 24 Hr. Gal.	Pump House			Tanks		Water Cranes		No.		No. of Stalls		
						No.	Pumps	Floor Area Sq. Ft.	No.	Capacity Gal.	No.	No.	Frame	Other	Total	Used as Rep. Shp.	No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Atchison, Topeka & Santa Fe Ry.	2	300	150	2	445,100	1	2	880	3	545,000	5	2		2	45	8	2
Baltimore & Ohio R. R.	1	200	150	1	250,000				1	60,000	3	1		1	27		1
Baltimore & Ohio Chicago Terminal R. R.	2	120	240	6	204,000		2		4	250,000	8	2		3	45		2
Calumet, Hammond & Southeastern R. R.														1	1		
Chesapeake & Ohio Ry. of Indiana	Nothing in Zone A																
Chicago & Alton R. R.	1	70	325	4	1,500,000				1	44,000	4	2		1	22		1
Chicago & Calumet River R. R.	1	50	8	1	18,000				1	10,000							
Chicago & Eastern Illinois R. R.	Nothing in Zone A																
Chicago & Erie R. R.	Nothing in Zone A																
Chicago & Illinois Western R. R.	Nothing in Zone A																
Chicago & North Western Ry.	3	3,677	3,380	9	1,802,000				9	485,100	19	8		5	140		7
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	6	1,500	845	12	1,038,250		3		12	680,000	13	5		2	73		4
Chicago, Burlington & Quincy R. R.	3	300	521	5	583,500				4	271,000	8	3		2	53	10	2
Chicago Great Western R. R.	1	200	85	2	144,000				1	50,000	1	1		1	13		1
Chicago, Indiana & Southern R. R.	Nothing in Zone A																
Chicago, Indianapolis & Louisville Ry.	Nothing in Zone A																
Chicago Junction Ry.	2	400	250	4	1,010,000	2	2	825	5	455,000	9	3		1	25	2	1
Chicago, Milwaukee & St. Paul Ry.	3	660	800	7	675,750	1		150	10	339,844	8	4		2	71	8	2
Chicago River & Indiana R. R.	None to Report																
Chicago, Rock Island & Pacific Ry.	2	535	320	4	418,750				4	109,700	3	1		2	77		2
Chicago Short Line Ry.	1	60	45	2	55,000				1	30,000	2			1	4		
Chicago Union Transfer Ry.												1		1	10	5	1
Chicago, West Pullman & Southern R. R.	2	275	42	2	48,700						3	2		2	6		
Elgin, Joliet & Eastern Ry.	3	370	168	2	500,000				3	140,000	4	3	2	1	14		2
Grand Trunk Western Ry.	1	200	220	1	330,000		2		2	110,000	3	2		1	25		1
Illinois Central R. R.	6	1,350	980	4	875,000	1	3	1,750	8	335,000	5	12		4	108		4
Illinois Northern Ry.	1	200	40	1	48,000						1	1		1	6		
Indiana Harbor Belt R. R.	Nothing in Zone A																
Lake Shore & Michigan Southern Ry.	1	240	500	7	1,671,300	2	6	240	8	394,100	9	2		1	19		3
Manufacturers' Junction Ry.	Nothing in Zone A																
Michigan Central R. R.	2	185	260	3	420,000	3	4	1,392	3	260,000	2	3		2	16	1	2
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Nothing in Zone A																
New York, Chicago & St. Louis R. R.	1	1,500	160	1	328,500				1	48,000	2	1		1	16		1
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	2	38	185	4	565,700	1	2	518	4	200,000	4	2	1	1	18	1	1
Pittsburgh, Fort Wayne & Chicago Ry.	2	700	550	6	661,600	2	2	552	6	300,000	11	2		2	25	4	2
Pullman Railroad	1	450	24	2	41,000						2	1		1	10	2	1
Wabash Railroad	1		180	1	200,000	1	1	168	1	48,500	2	1		1	20	5	1
Totals	51	13,580	10,428	93	13,834,150	14	29	6,475	92	5,165,244	131	65	3	43	891	16	44

TABLE CLXVI (Continued). SUMMARY OF STATISTICAL FACTS RELATING TO LOCOMOTIVE TERMINAL FACILITIES. ZONE A
(Basis of 1912)

Railroad	Shop Buildings												Transfer Tables	Light and Power Stations			Gas Plants	Total Buildings	
	Erecting		Machine		Boiler		Tender		Blacksmith		Other								
	No.	Floor Area Sq. Ft.	No.	Floor Area Sq. Ft.	No.	Floor Area Sq. Ft.	No.	Floor Area Sq. Ft.	No.	Floor Area Sq. Ft.	No.	Floor Area Sq. Ft.		No.	Boiler Horse-Power	Floor Area Sq. Ft.	No.	No.	Floor Area Sq. Ft.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Atchison, Topeka & Santa Fe Ry			1	8,000	2	5,000			1	290	1	1,100		1	450	1,390		7	16,660
Baltimore & Ohio R. R.			1	8,120	1	5,000			1	5,740	3	11,060						6	29,920
Baltimore & Ohio Chicago Terminal R. R.														1b	750				
Calumet, Hammond & Southeastern R. R.																			
Chesapeake & Ohio Ry. of Indiana																			
Chicago & Alton R. R.			1	345					1	345				1	240	4,720		3	5,410
Chicago & Calumet River R. R.																			
Chicago & Eastern Illinois R. R.																			
Chicago & Erie R. R.																			
Chicago & Illinois Western R. R.																			
Chicago & North Western Ry		82,800a	3	83,296	1	36,000	1	27,520	2	32,653	4	44,040	3	2	3,750	22,520	1	14	328,829
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago			2	24,750										4c	2,785	13,964		4	38,714
Chicago Burlington & Quincy R. R.														2c	650				
Chicago Great Western R. R.			1	1,995														1	1,995
Chicago, Indiana & Southern R. R.																			
Chicago, Indianapolis & Louisville Ry																			
Chicago Junction Ry			1	12,000	1	2,500			1	2,500	1	8,000		1	130	1,800		7	27,025
Chicago, Milwaukee & St. Paul Ry			2	6,112					2	2,984	11	11,151		2	1,900	8,220		18	28,617
Chicago River & Indiana R. R.																			
Chicago, Rock Island & Pacific Ry			1	4,032					1	2,876	1	16,000	1	1	2,000	8,536		4	31,444
Chicago Short Line Ry																			
Chicago Union Transfer Ry											2	2,136						2	2,136
Chicago, West Pullman & Southern R. R.			1	432														1	432
Elgin Joliet & Eastern Ry																			
Grand Trunk Western Ry			1	4,134	1	2,065			1	2,808				1	140	2,120		4	11,127
Illinois Central R. R.	2	122,575	1	88,000	1	66,550			2	71,300	6	196,901	6	2	4,650	12,160		15	559,236
Illinois Northern Ry			1	5,400														1	5,400
Indiana Harbor Belt R. R.																			
Lake Shore & Michigan Southern Ry			2	17,174							13	31,655		1	200	2,530		18	51,599
Manufacturers' Junctinn Ry																			
Michigan Central R. R.									1	960				1	50	960		5	3,312
Minneapolis, St. Paul & Sault Ste. Marie Ry																			
New York, Chicago & St. Louis R. R.	1	12,800	1	26,100					1	7,000	3	32,300	2	1		2,250		7	80,450
Pittsburgh, Cincinnati, Chicago & St. Louis Ry																		1	518
Pittsburgh, Fort Wayne & Chicago Ry			1	16,317					1	2,688			1	2	1,400	9,450		6	29,007
Pullman Railroad																			
Wabash Railroad																		1	168
Totals	3	218,175	21	306,207	7	117,115	1	27,520	15	132,144	45	354,343	13	23	19,095	90,620	1	125d	1,252,599

a Part of machine shop.
b Does not include area of basements in terminal stations used for this purpose.
c In engine houses.
d Does not include coaling stations, tanks and engine houses.
e Two of these power plants are in basements of other buildings.

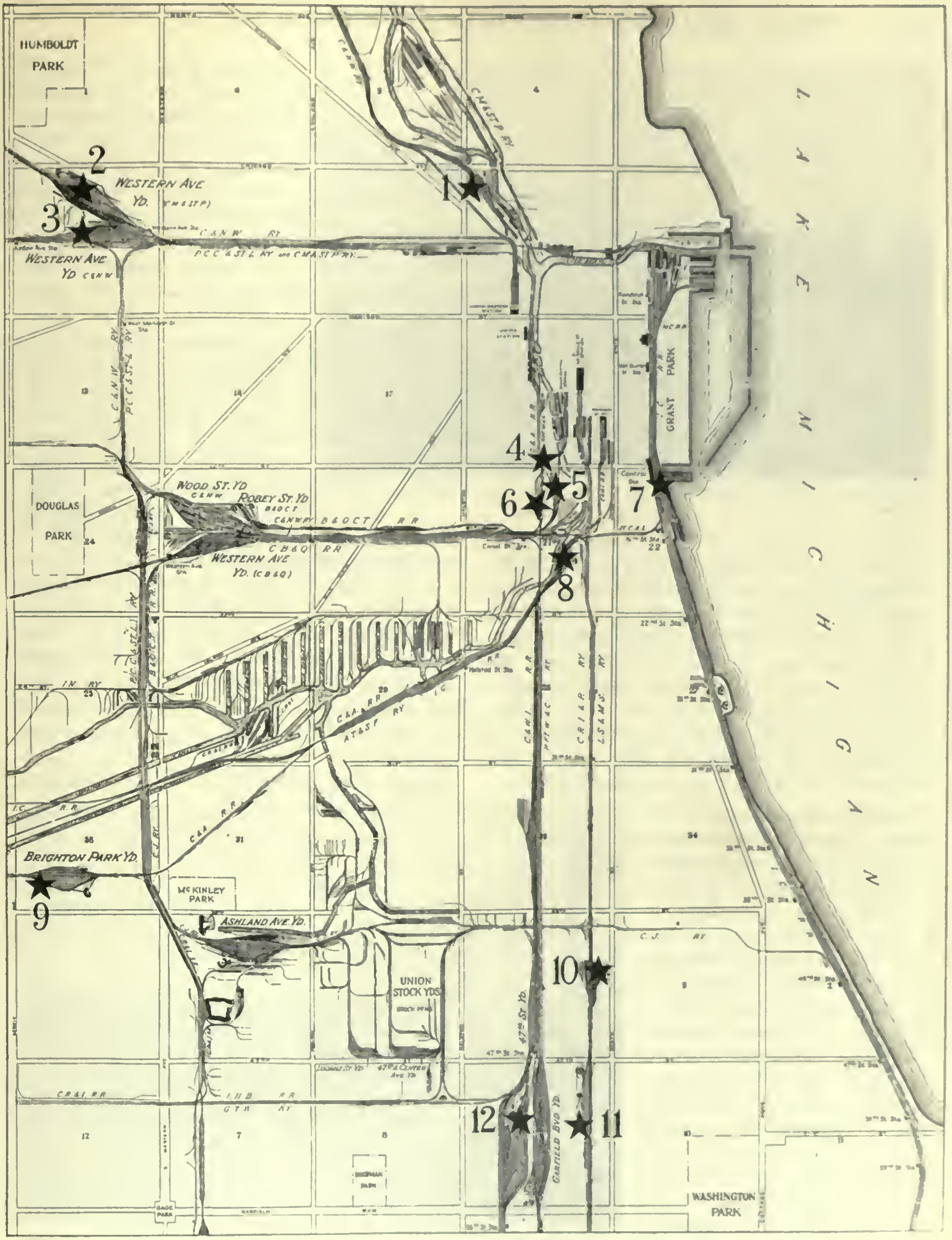

FIG. 354. LOCATIONS OF PRINCIPAL COACH YARDS, CHICAGO TERMINALS

FIG. 355. COACH YARDS. Twelfth Street Coach Yard of the Illinois Central Railroad.

which has a yard at 43d Street, about four miles from the La Salle Street Station; in that of the Chicago, Rock Island & Pacific Railway, which has a yard at 51st Street, about five miles from the La Salle Street Station; in that of the Chicago & Alton Railroad, which has a coach yard near 37th Street and Kedzie Avenue, nearly six miles from the Union Station; and in that of the Chicago, Milwaukee & St. Paul Railway, which utilizes for coaches a part of the Western Avenue yard, about three and a half miles from the Union Station.

Facilities are provided at coach yards for light repairs to passenger cars, such as are necessary in replacing broken parts, in fitting new brasses to bearings and in cleaning. Gas lines for supplying coaches with lighting gas, and steam lines for heating them preparatory to making up trains are also conveniently placed. The yards are usually lighted by electricity. Thus, a large yard involves a considerable plant for the care and handling of the passenger coaches used in both through and suburban services, and operations are carried on almost continuously. In some cases, different classes of coaches are cared for at different localities. For example, the Illinois Central Railroad uses the 12th Street Yard principally for coaches in through passenger service, the suburban coaches being cared for at Randolph Street or at Burnside.

FIG. 356. COACH YARDS. Coach Yard of the Chicago & North Western Railway at Western Avenue.

The largest coach yard in Chicago is that of the Illinois Central Railroad at 12th Street, which has more than nine miles of track. Other large coach yards include the yards of the Chicago & North Western Railway and the Chicago, Milwaukee & St. Paul Railway at Western Avenue, that of the Chicago, Burlington & Quincy Railroad at 14th Street and Stewart Avenue, that of the Chicago & Western Indiana Railroad at 51st and Butler streets, that of the Chicago, Rock Island & Pacific Railway near 51st Street and Wentworth Avenue, that of the Illinois Central Railroad at Burnside, and that of the Chicago & North Western Railway near Erie and Halsted streets. General views of representative coach yards in Chicago are presented as figs. 355 to 360, inclusive.

201.20 The Activities of the Terminals of

Chicago:* The service of trunk line steam railroads involves the handling of freight and passenger traffic, the movements incident to which are often complex. The service performed by the trunk line railroads in the Chicago terminals has, for the various purposes of the Committee, been divided into five classes, as follows:

1. Through Passenger Service, or the handling of passengers between Chicago and points beyond the Committee's Area of Investigation.
2. Suburban Passenger Service, or handling of passengers between different points within the Committee's Area of Investigation or between points within this area and points immediately outside of it.
3. Road Freight Service, or the handling of freight traffic between Chicago and points beyond the Committee's Area of Investigation.
4. Freight Transfer Service, or the handling of freight traffic between the various railroad yards or between other points within the Committee's Area of Investigation.
5. Yard Service, or the handling of traffic within the limits of any of the railroad yards within the Committee's Area of Investigation.

FIG. 357. COACH YARDS. Coach Yard of the Lake Shore & Michigan Southern Railway at 43d Street.

The relative importance of each of these several services varies with different roads, depending on the general character of business performed by each road. Some roads confine their service entirely to switching and transfer movements; a number of them do not operate suburban passenger service.

The extent of the traffic handled in the Chicago terminals, as evidenced by the record for representative days, is shown by roads in tables CLXVII to CLXXI, inclusive. This record shows that on October 19, 1912, there were handled in the Chicago Terminals 532 through passenger trains and 872 suburban passenger trains and that during the week of October 8-14, 1912, there were 209,739 trailing tons handled in trains of more than 3,000 trailing tons each.

Photographs of typical through passenger, suburban passenger and freight trains within the Area of Investigation are reproduced as figs. 361 to 376, inclusive.

Many different types of locomotives are employed by the various railroads to handle the traffic of the Chicago terminals. In light switching movements and in suburban passenger service locomotives of relatively light weight are used; in the road freight and through passenger services heavy locomotives are required. Illustrations of representative types of locomotives are presented as figs. 377 to 390, inclusive.

FIG. 358. COACH YARDS. Empire Slip Coach Yard of the Baltimore & Ohio Chicago Terminal Railroad, near 12th Street and the Chicago River.

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* Further facts relating to railroad [illegible] Chicago are presented in chapters [illegible]

FIG. 359. COACH YARDS. Coach Yard of the Atchison, Topeka & Santa Fe Railway at 18th Street (North End).

FIG. 360. COACH YARDS. Coach Yard of the Atchison, Topeka & Santa Fe Railway at 18th Street (South End).

TABLE CLXVII. PASSENGER TRAIN MOVEMENTS IN THE CITY OF CHICAGO
WEDNESDAY, OCTOBER 19, 1912

Railroad	Passenger Trains				Passenger Cars			
	Through		Suburban		Through		Suburban	
	Arrived No.	Departed No.	Arrived No.	Departed No.	Arrived No.	Departed No.	Arrived No.	Departed No.
1	2	3	4	5	6	7	8	9
Atchison, Topeka & Santa Fe Ry	9	10	0	0	52	71	0	0
Baltimore & Ohio R. R.	7	6	0	0	40	33	0	0
Baltimore & Ohio Chicago Terminal R. R.	0	0	6	6	0	0	17	17
Calumet, Hammond & Southeastern R. R.	0	0	0	0	0	0	0	0
Chesapeaka & Ohio Ry. of Indiana	3	3	0	0	10	10	0	0
Chicago & Alton R. R.	8	9	2	1	67	58	7	3
Chicago & Calumet River R. R.	0	0	0	0	0	0	0	0
Chicago & Eastern Illinois R. R.	11	11	2	2	75	76	7	7
Chicago & Eria R. R.	6	5	0	0	34	35	0	0
Chicago & Illinois Western R. R.	0	0	0	0	0	0	0	0
Chicago & North Western Ry	42	46	123	120	278	291	601	562
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	0	0	14	16	0	0	37	39
Chicago, Burlington & Quincy R. R.	19	17	29	29	144	140	133	134
Chicago Great Western R. R.	4	4	0	0	26	26	0	0
Chicago, Indiana & Southern R. R.	3	3	0	0	10	10	0	0
Chicago, Indianapolis & Louisville Ry	7	7	0	0	42	40	0	0
Chicago Junction Ry	0	0	0	0	0	0	0	0
Chicago, Milwaukee & St. Paul Ry	32	28	28	21	223	194	111	85
Chicago River & Indiana R. R.	0	0	0	0	0	0	0	0
Chicago, Rock Island & Pacific Ry	15	16	42	43	91	105	178	183
Chicago Short Line Ry	0	0	0	0	0	0	0	0
Chicago Union Transfer Ry	0	0	0	0	0	0	0	0
Chicago, West Pullman & Southern R. R	0	0	0	0	0	0	0	0
Elgin, Joliet & Eastern Ry	0	0	0	0	0	0	0	0
Grand Trunk Western Ry	7	6	5	5	37	37	25	25
Illinois Central R. R.	21	21	157	156	138	135	715	721
Illinois Northern Ry	0	0	0	0	0	0	0	0
Indiana Harbor Belt R. R.	0	0	0	0	0	0	0	0
Laka Shore & Michigan Southern Ry	16	15	20	20	123	106	104	94
Manufacturers' Junction Ry	0	0	0	0	0	0	0	0
Michigan Central R. R.	14	12	0	0	121	98	0	0
Minneapolis, St. Paul & Sault Ste. Marie Ry	6	6	0	0	34	34	0	0
Naw York, Chicago & St. Louis R. R.	3	3	0	0	16	19	0	0
Pere Marquette R. R.	5	5	0	0	29	27	0	0
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	4	2	0	0	29	7	0	0
Pittshurgh, Fort Wayne & Chicago Ry	20	20	11	11	160	154	35	39
Pullman Railroad	0	0	0	0	0	0	0	0
Wahash Railroad	8	7	6	7	45	45	14	16
Totals	270	262	445	437	1,824	1,751	1,984	1,925

TABLE CLXVIII. ROAD FREIGHT TRAINS CONSISTING OF 3,000, OR MORE, TRAILING TONS, HANDLED IN THE CHICAGO TERMINALS DURING THE WEEK OF OCTOBER 8-14, INCLUSIVE, 1912

Day in Oct., 1912	Railroad	Movement		Number of Cars in Train	Weight, Trailing Tons
		From	To		
1	2	3	4	5	6
8	Baltimore & Ohio R. R.	Curtis Yard	So. Chicago Yard	53	3,500
9	Chicago & Alton R. R.	Argo	Brighton Park Yard	75	3,000
8	Chicago & North Western Ry	Niles Center	40th Avenue Yard	63	3,054
8	Chicago & North Western Ry	Niles Center	40th Avenue Yard	70	3,029
8	Chicago & North Western Ry	Niles Center	40th Avenue Yard	78	3,000
8	Chicago & North Western Ry	Niles Center	40th Avenue Yard	66	3,078
8	Chicago & North Western Ry	40th Avenue Yard	Niles Center	64	3,006
9	Chicago & North Western Ry	Niles Center	40th Avenue Yard	81	3,015
9	Chicago & North Western Ry	Niles Center	40th Avenue Yard	94	3,007
9	Chicago & North Western Ry	Niles Center	40th Avenue Yard	65	3,002
9	Chicago & North Western Ry	40th Avenue Yard	Niles Center	58	3,165
10	Chicago & North Western Ry	Niles Center	40th Avenue Yard	77	3,000
10	Chicago & North Western Ry	Niles Center	40th Avenue Yard	80	3,005
10	Chicago & North Western Ry	Niles Center	40th Avenue Yard	69	3,018
10	Chicago & North Western Ry	Niles Center	40th Avenue Yard	73	3,004
12	Chicago & North Western Ry	Niles Center	40th Avenue Yard	80	3,016
12	Chicago & North Western Ry	40th Avenue Yard	Niles Center	84	3,000
13	Chicago & North Western Ry	40th Avenue Yard	Niles Center	49	3,126
13	Chicago & North Western Ry	Niles Center	40th Avenue Yard	70	3,026
9	Chicago, Burlington & Quincy R. R	La Grange	Hawthorne Yard	64	3,659
13	Chicago, Burlington & Quincy R. R	La Grange	Hawthorne Yard	59	3,510
14	Chicago, Burlington & Quincy R. R	La Grange	Hawthorne Yard	68	3,310
14	Chicago, Burlington & Quincy R. R	La Grange	Hawthorne Yard	70	3,435
14	Chicago, Indiana & Southern R. R.	Gibson	Englewood	40	3,405*
13	Chicago, Milwaukee& St. Paul Ry.	Morton Grove	Galewood	91	3,511
14	Chicago, Milwaukee & St. Paul Ry.	Morton Grove	Galewood	73	3,066
9	Elgin, Joliet & Eastern Ry	Ivanhoe	Kirk Yard	35	3,065
8	Illinois Central R. R.	Harvey	Chicago	78	3,120
9	Illinois Central R. R.	Harvey	Fordham Yard	77	3,080
9	Illinois Central R. R.	Harvey	Fordham Yard	75	3,000
9	Illinois Central R. R.	Fordham Yard	Harvey	75	3,000
9	Illinois Central R. R.	Fordham Yard	Harvey	87	3,400
10	Illinois Central R. R.	Harvey	Fordham Yard	75	3,000
10	Illinois Central R. R.	Harvey	Fordham Yard	78	3,120
10	Illinois Central R. R.	Harvey	Fordham Yard	80	3,200
10	Illinois Central R. R.	Fordham Yard	Harvey	75	3,000
10	Illinois Central R. R.	Fordham Yard	Harvey	87	3,480
11	Illinois Central R. R.	Harvey	Fordham Yard	80	3,200
11	Illinois Central R. R.	Fordham Yard	Harvey	86	3,440
11	Illinois Central R. R.	Fordham Yard	Harvey	79	3,160
12	Illinois Central R. R.	Fordham Yard	Harvey	75	3,000
13	Illinois Central R. R.	Harvey	Fordham Yard	79	3,160
13	Illinois Central R. R.	Harvey	Chicago	91	3,640
13	Illinois Central R. R.	Fordham Yard	Chicago	91	3,640
14	Illinois Central R. R.	Harvey	Fordham Yard	89	3,560
14	Illinois Central R. R.	Harvey	Chicago	83	3,320
8	Lake Shore & Michigan Southern Ry	Pine Yard	Indiana Harbor	86	3,677
8	Lake Shore & Michigan Southern Ry	Indiana Harbor	Pine	80	3,670
8	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	70	4,032
9	Lake Shore & Michigan Southern Ry	South Chicago	Indiana Harbor	101	3,535
9	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	64	3,600
9	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	70	4,065
10	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	68	3,160
10	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	68	3,256
11	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	68	4,000
11	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	84	3,317
12	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	66	3,969
12	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	74	3,950
12	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	62	3,995
13	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	71	4,066
14	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	97	3,405
14	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	69	4,034
14	Lake Shore & Michigan Southern Ry	Pine	Indiana Harbor	81	3,500

Total number of trains weighing more than 3,000 tons, operated in week, Oct. 8-14, 1912	63
Total number of cars in these trains	4,668
Average number of cars in train	74
Total trailing tons in the above trains	209,739
Average trailing load in the above trains, tons	3.330

* Report covers one day only.

TABLE CLXIX. ROAD FREIGHT TRAINS CONSISTING OF MORE THAN 2,500 TRAILING TONS, HANDLED IN THE CHICAGO TERMINALS DURING THE WEEK OF OCTOBER 8-14, INCLUSIVE, 1912

Railroad*	Road Freight Trains						
	Total Trains Moved No.	Having more than 2,500 Trailing Tons					
		Trains No.	Per Cent Trains Moved Col. 2	Cars No.	Trailing Load Tons	Averages	
						Cars in Trains No.	Trailing Load Tons
1	2	3	4	5	6	7	8
Baltimore & Ohio R. R.	143	1	0.7	53	3,500	53	3,500
Chicago & Alton R. R.	111	8	7.2	541	22,150	67	2,769
Chicago & North Western Ry.	425	35	8.2	2,492	99,938	71	2,855
Chicago, Burlington & Quincy R. R.	604	11	1.8	647	32,469	59	2,952
Chicago, Indiana & Southern R. R.	19†	1	5.3	40	3,405	40	3,405
Chicago, Milwaukee & St. Paul Ry.	333	9	2.7	589	25,163	65	2,796
Elgin, Joliet & Eastern Ry.	352	25	7.1	1,151	67,630	46	2,705
Illinois Central R. R.	200	36	18.0	2,709	108,280	75	3,007
Lake Shore & Michigan Southern Ry.	293	32	10.9	2,336	104,387	76	3,262
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	335	4	1.2	252	10,595	63	2,648
Pittsburgh, Fort Wayne & Chicago Ry.	395	3	0.7	165	7,925	55	2,641
Totals	3,210	165	5.1	10,975	485,442	66	2,942

* Roads not shown moved no trains of more than 2,500 trailing tons during the week covered by the report.

† Report covers one day only.

FIG. 361. THROUGH PASSENGER TRAINS. The "20th Century Limited" of the Lake Shore & Michigan Southern Railway.

FIG. 362. THROUGH PASSENGER TRAINS. The "Broadway Limited" of the Pittsburgh, Ft. Wayne & Chicago Railway (Pennsylvania).

TABLE CLXX. DAILY AVERAGE NUMBER OF TRAINS AND CARS CROSSING THE CHICAGO CITY LIMITS

Direction of Movement	Av. No. of Trains		Average Number of Cars			
	Road Freight	Freight Transfer	Road Freight		Freight Transfer	
			Through	Local	Through	Local
1	2	3	4	5	6	7
In-bound	218	163	799	5,077	338	3,522
Out-bound	225	159	1,093	5,029	459	3,305
Totals	443	322	1,892	10,106	797	6,827

TABLE CLXXI. PERCENTAGE OF THE TOTAL ROAD AND TRANSFER FREIGHT TRAFFIC HANDLED BY EACH RAILROAD WITHIN THE PROPOSED LIMITS OF ELECTRIC OPERATION

(Ton-Mile Basis, Year 1912)

Railroad	Percentage of Total Freight Traffic Handled	
	Road Freight	Transfer, Freight
Atchison, Topeka & Santa Fe Ry.	2.50	0.63
Baltimore & Ohio R. R.	5.32	2.76
Baltimore & Ohio Chicago Terminal R. R.	....	5.61
Calumet, Hammond & Southeastern R. R.	....	....
Chesapeake & Ohio Ry. of Indiana	....	0.51
Chicago & Alton R. R.	1.79	1.53
Chicago & Calumet River R. R.	....	....
Chicago & Eastern Illinois R. R.	1.09	3.26
Chicago & Erie R. R.	....	....
Chicago & Illinois Western R. R.	....	....
Chicago & North Western Ry.	14.29	12.46
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	....	25.79
Chicago, Burlington & Quincy R. R.	0.96	5.15
Chicago Great Western R. R.	0.66	0.16
Chicago, Indiana & Southern R. R.	0.81	....
Chicago, Indianapolis & Louisville Ry.	0.16	1.75
Chicago Junction Ry.	....	....
Chicago, Milwaukee & St. Paul Ry.	8.75	8.25
Chicago River & Indiana R. R.	....	....
Chicago, Rock Island & Pacific Ry.	0.62	4.63
Chicago Short Line Ry.	....	....
Chicago Union Transfer Ry.	....	....
Chicago, West Pullman & Southern R. R.	....	0.10
Elgin, Joliet & Eastern Ry.	....	1.54
Grand Trunk Western Ry.	3.39	0.46
Illinois Central R. R.	10.18	4.52
Illinois Northern Ry.	....	0.24
Indiana Harbor Belt R. R.	....	1.78
Lake Shore & Michigan Southern Ry.	14.99	2.61
Manufacturers' Junction Ry.	....	0.03
Michigan Central R. R.	1.10	3.66
Minneapolis, St. Paul & Sault Ste. Marie Ry.	....	0.81
New York, Chicago & St. Louis R. R.	3.13	1.87
Pere Marquette R. R.	0.53	1.08
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	9.97	3.63
Pittsburgh, Fort Wayne & Chicago Ry.	13.96	3.51
Pullman Railroad	....	....
Wabash Railroad	5.80	1.67
Totals	100.00	100.00

FIG. 363. THROUGH PASSENGER TRAINS. The "Wolverine" of the Michigan Central Railroad.

FIG. 364. THROUGH PASSENGER TRAINS. The "Golden Special" of the Chicago & North Western Railway.

FIG. 365. THROUGH PASSENGER TRAINS. The "Denver Limited" of the Chicago, Burlington & Quincy Railroad.

FIG. 366. THROUGH PASSENGER TRAINS. The "Day Light Special" of the Illinois Central Railroad.

FIG. 367. THROUGH PASSENGER TRAINS. The "California Limited" of the Atchison, Topeka & Santa Fe Railway.

FIG. 368. THROUGH PASSENGER TRAINS. The "Alton Limited" of the Chicago & Alton Railroad.

FIG. 369. SUBURBAN PASSENGER TRAINS. Flossmoor Suburban Train of the Illinois Central Railroad at the 67th Street Station. The train consists of a Forney type locomotive and six coaches.

FIG. 370. SUBURBAN PASSENGER TRAINS. Suburban Train of the Chicago & North Western Railway at Proviso. This train consists of a ten-wheel locomotive and four coaches.

FIG. 371. SUBURBAN PASSENGER TRAINS. Suburban Train of the Chicago, Rock Island & Pacific Railway at Brainerd Station. This train consists of an American type locomotive and three coaches.

FIG. 372. SUBURBAN PASSENGER TRAINS. Suburban Train of the Pittsburgh, Fort Wayne & Chicago Railway at Englewood Station. This train consists of a ten-wheel locomotive and three coaches.

FIG. 373. SUBURBAN PASSENGER TRAINS. Suburban Train of the Chicago, Burlington & Quincy Railroad at Riverside Station. This train consists of a ten-wheel type locomotive and three coaches.

FIG. 374. SUBURBAN PASSENGER TRAINS. Suburban Train of the Chicago & Western Indiana Railroad at Dolton Station.

FIG. 375. FREIGHT TRAINS. Transfer Train on the Indiana Harbor Belt Railroad.

FIG. 376. FREIGHT TRAINS. Transfer Train on the Illinois Central Railroad.

FIG. 377. LOCOMOTIVES. Passenger Locomotive of the Pacific Type. Chicago & North Western Railway.

FIG. 378. LOCOMOTIVES. Passenger Locomotive of the Atlantic Type. Pittsburgh, Fort Wayne & Chicago Railway.

FIG. 379. LOCOMOTIVES. Prairie Type Locomotive. Chicago, Burlington & Quincy Railroad.

FIG. 380. LOCOMOTIVES Passenger Locomotive of the Ten-wheel Type. Chicago, Milwaukee & St. Paul Railway.

FIG. 381. LOCOMOTIVES. Passenger Locomotive of the American Type. Atchison, Topeka & Santa Fe Railway.

FIG. 382. LOCOMOTIVES. Passenger Locomotive of the American Type. One of the older and lighter of the passenger locomotives used in Chicago, now engaged in Suburban Service. Wabash Railroad.

FIG. 383. LOCOMOTIVES. Suburban Passenger Locomotive of the Forney Type. Illinois Central Railroad.

FIG. 384. LOCOMOTIVES. Freight Locomotive of the Mikado Type. Chicago & North Western Railway.

FIG. 385. LOCOMOTIVES. Freight Locomotive of the Consolidation Type. Lake Shore & Michigan Southern Railway.

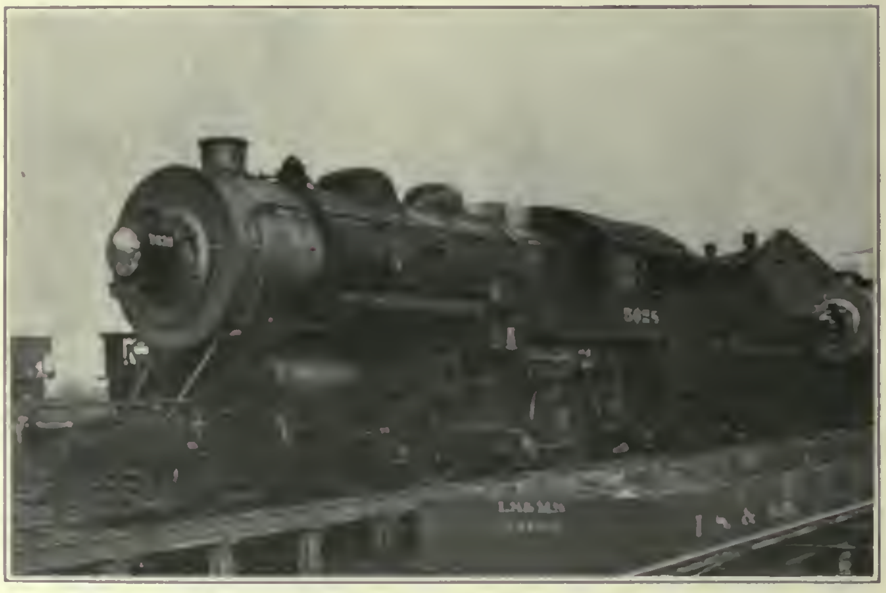

FIG. 386. LOCOMOTIVES. Locomotive of the Mogul Type. An older type of freight locomotive. Grand Trunk Western Railway.

FIG. 387. LOCOMOTIVES. Switching and Transfer Locomotive of the Eight-wheel Type. Chicago & Eastern Illinois Railroad.

FIG. 388. LOCOMOTIVES. Switching Locomotive of the Six-wheel Type. Lake Shore & Michigan Southern Railway.

FIG. 389. LOCOMOTIVES. Switching Locomotive of the Four-wheel Type. At present, only a few locomotives of this type remain in service in Chicago. Illinois Northern Railway.

FIG. 390. LOCOMOTIVES. Switching Locomotive of the Four-wheel Type. This is a very light locomotive of the older type, used in switching service. At present it is engaged in light yard service. Chicago, Milwaukee & St. Paul Railway.

202. STATISTICS OF OPERATION, TRAFFIC AND TRAIN MOVEMENTS

SYNOPSIS: This chapter describes the methods employed by the Committee in compiling the statistical facts which have formed the basis for the various studies relating to electrification. The results constitute a record of the activities of the Chicago terminals for the year 1912; they show the number of locomotive-miles performed by each road in each service, the number of ton-miles and the amount of coal consumed. Certain facts relating to locomotive performance are also presented.

202.01 Statistical Facts Required: The development of the plan of electrifying Chicago's railroad terminals and the preparation of the estimates of the cost required the compilation of a mass of statistical facts relating to the amount of traffic handled, the extent of train movements conducted within the Area of Investigation and other aspects of the present steam operation. Facts relating to the amount of fuel consumed by locomotives also have been required in connection with estimates of the amount of fuel consumed within the Area of Investigation (chapter 104), upon which has been based the study of smoke (chapter 105).

Full information regarding the extent of the existing railroad service within the proposed limits of electrification hereinafter defined, its hourly and geographic distribution and its daily and seasonal variations, was essential to a determination of the amount of electric energy required to perform with electric motive power the service now performed with steam power. Because of the fundamental importance of these statistics, every precaution was taken in compiling them to safeguard against errors and to render them complete. The methods employed to accomplish this and a summary of the facts obtained are presented in the sections which follow.

202.02 Report Forms: Facts relating to operation and to the movement of traffic were obtained from reports prepared and submitted by the railroads. To insure the inclusion in these reports of all the required facts, special forms were employed upon which the desired information could be entered. Tentative copies of such forms were prepared by the Committee after consultation with representatives of various railroads. These were sent to all the railroads operating within the Area of Investigation, and later representatives of the transportation departments of more than twenty railroads met with the Committee's staff to consider in detail the plan for obtaining the information. At this meeting the railroad representatives appointed a committee of the transportation officers of eight railroads to co-operate with the Committee's staff and to adopt final forms and methods.*

As a result of these conferences, forms were prepared and adopted. Reproductions of typical reports submitted on these forms are presented as figs. 391 to 395, inclusive.

It was recognized that the division of the switching service into "Yard Switching," "Freight Transfer" and "Passenger Transfer," as defined in the instructions printed on the forms furnished the railroads, is not fully in accordance with ordinary railroad practice. In the course of the discussion which took place at the conference to which reference has been made, some opposition to the preliminary blank, "Form 1," arose because of the separation of yard and transfer service. It was urged that these services are generally considered as one and that the two services require the same amount of coal. It was, however, regarded as important for the purposes of the Committee to report the two separately.

The forms called for the desired information in sufficient detail to enable the Committee to tabulate the data for each class of traffic and for each road by days and hours, by class of cars (that is, through or local) and by the geographic location of each movement.

The magnitude of the work involved in compiling the statistics which, in this report, are

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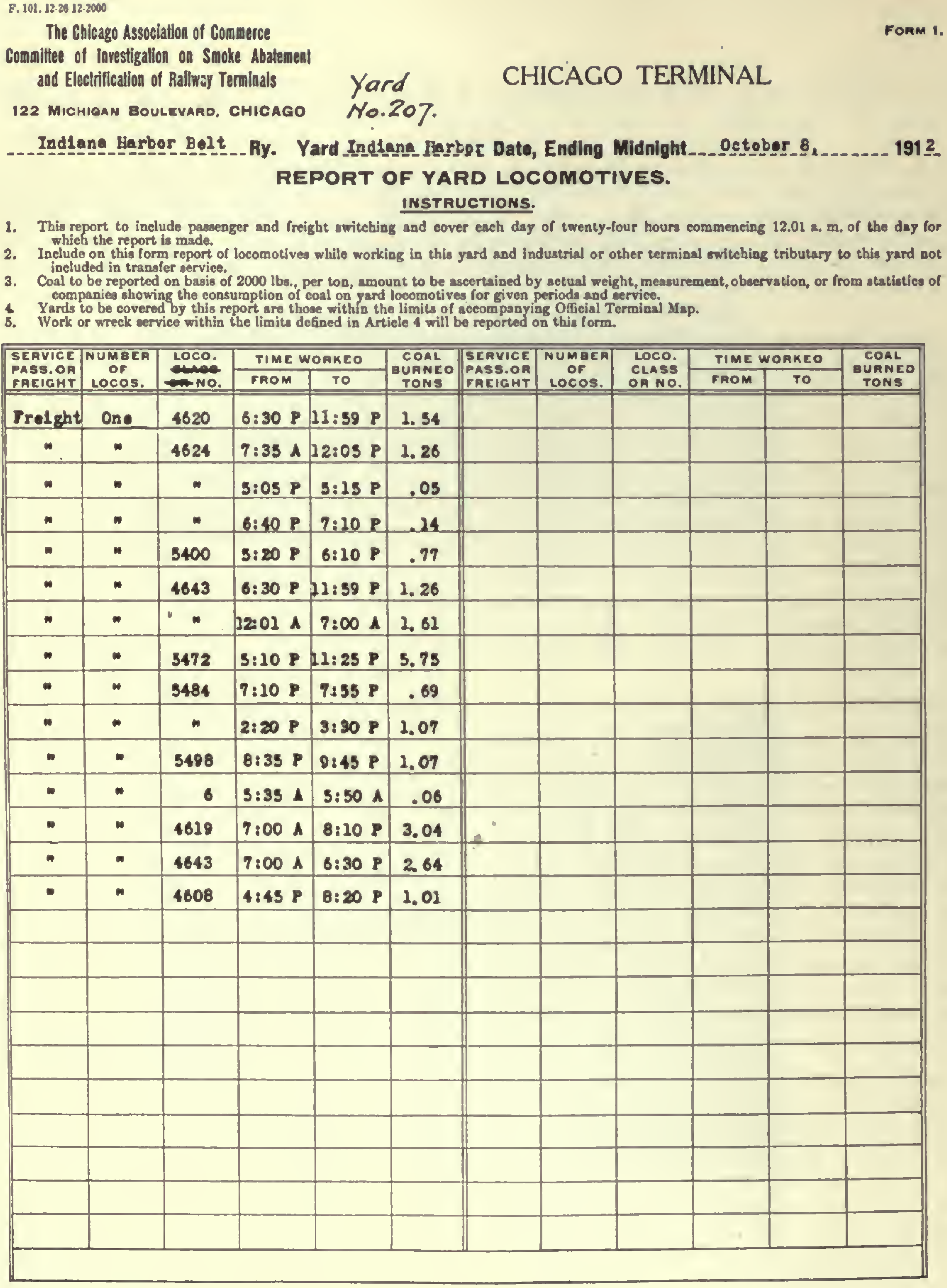
*See "Minutes of Meeting of Advisory Committee of Representatives of Railway Transportation Departments held Sept. 19, 1911." Bulletin I, Vol. II, and Circular Letter No. 24, dated Dec. 11, 1911, Archives of the Committee, Vol. B 11.



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The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals

122 MICHIGAN BOULEVARD, CHICAGO

Yard
No. 207.

FORM 1.

CHICAGO TERMINAL

Indiana Harbor Belt **Ry. Yard** Indiana Harbor **Date, Ending Midnight** October 8, **1912**

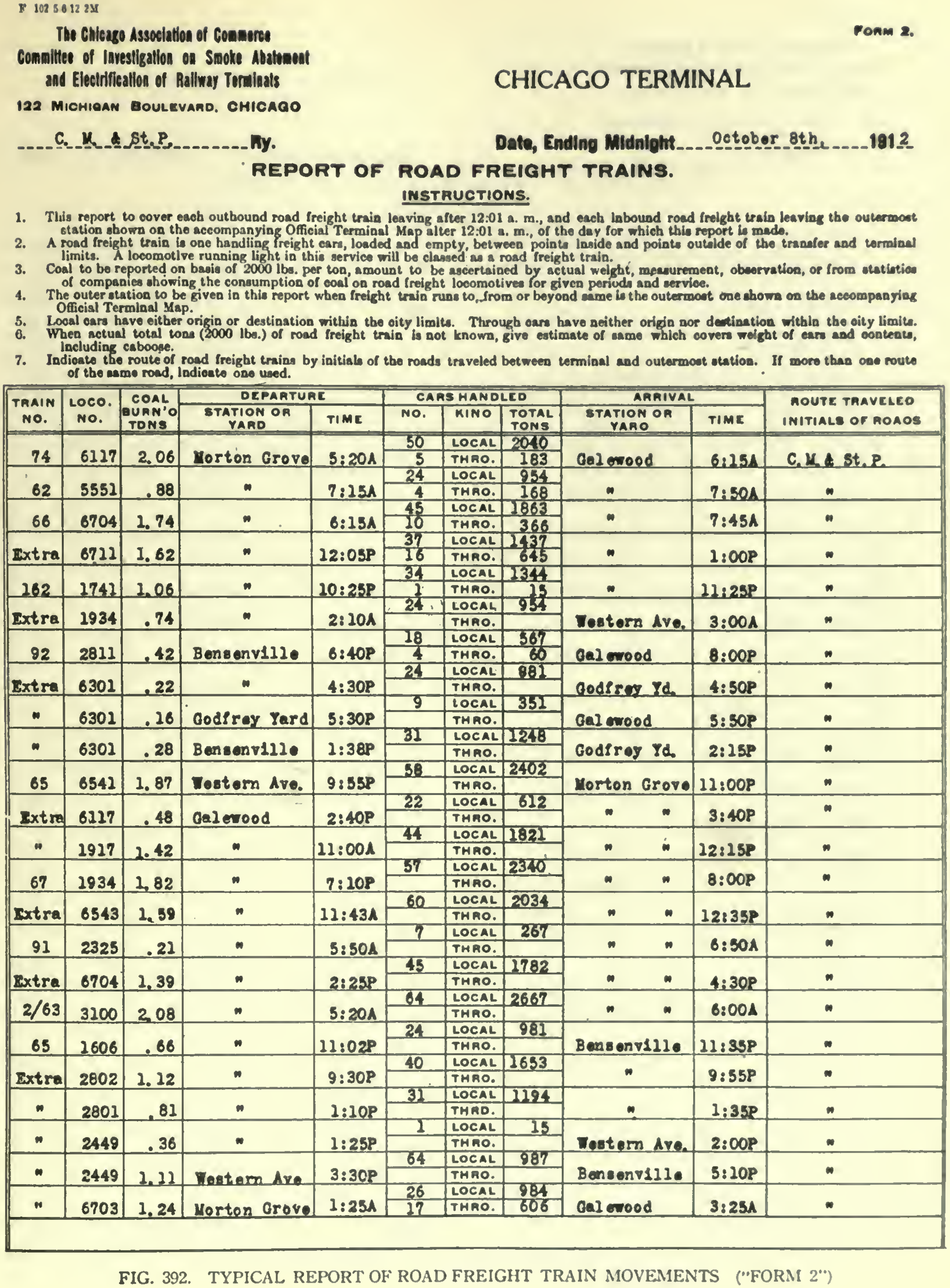
REPORT OF YARD LOCOMOTIVES.

INSTRUCTIONS.

1. This report to include passenger and freight switching and cover each day of twenty-four hours commencing 12.01 a. m. of the day for which the report is made.
2. Include on this form report of locomotives while working in this yard and industrial or other terminal switching tributary to this yard not included in transfer service.
3. Coal to be reported on basis of 2000 lbs., per ton, amount to be ascertained by actual weight, measurement, observation, or from statistics of companies showing the consumption of coal on yard locomotives for given periods and service.
4. Yards to be covered by this report are those within the limits of accompanying Official Terminal Map.
5. Work or wreck service within the limits defined in Article 4 will be reported on this form.

SERVICE PASS. OR FREIGHT	NUMBER OF LOCOS.	LOCO. ~~CLASS OR~~ NO.	TIME WORKED		COAL BURNED TONS	SERVICE PASS. OR FREIGHT	NUMBER OF LOCOS.	LOCO. CLASS OR NO.	TIME WORKED		COAL BURNED TONS
			FROM	TO					FROM	TO	
Freight	One	4620	6:30 P	11:59 P	1.54						
"	"	4624	7:35 A	12:05 P	1.26						
"	"	"	5:05 P	5:15 P	.05						
"	"	"	6:40 P	7:10 P	.14						
"	"	5400	5:20 P	6:10 P	.77						
"	"	4643	6:30 P	11:59 P	1.26						
"	"	"	12:01 A	7:00 A	1.61						
"	"	5472	5:10 P	11:25 P	5.75						
"	"	5484	7:10 P	7:55 P	.69						
"	"	"	2:20 P	3:30 P	1.07						
"	"	5498	8:35 P	9:45 P	1.07						
"	"	6	5:35 A	5:50 A	.06						
"	"	4619	7:00 A	8:10 P	3.04						
"	"	4643	7:00 A	6:30 P	2.64						
"	"	4608	4:45 P	8:20 P	1.01						

FIG. 391. TYPICAL REPORT OF YARD LOCOMOTIVE MOVEMENTS ("FORM 1")



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The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals
122 MICHIGAN BOULEVARD, CHICAGO

FORM 2.

CHICAGO TERMINAL

C. M. & St. P. **Ry.**

Date, Ending Midnight October 8th, **1912**

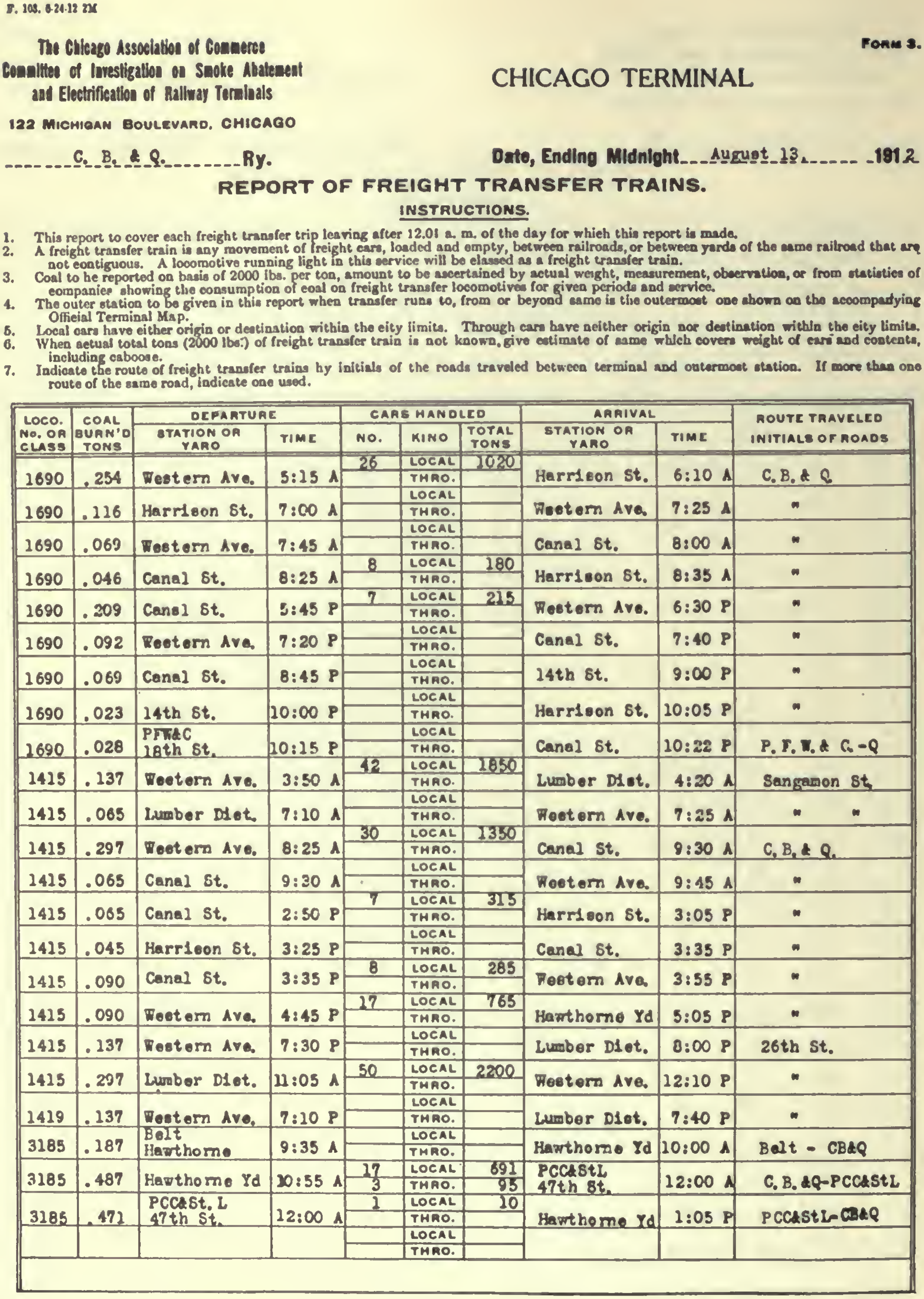
REPORT OF ROAD FREIGHT TRAINS.

INSTRUCTIONS.

1. This report to cover each outbound road freight train leaving after 12:01 a. m., and each inbound road freight train leaving the outermost station shown on the accompanying Official Terminal Map after 12:01 a. m., of the day for which this report is made.
2. A road freight train is one handling freight cars, loaded and empty, between points inside and points outside of the transfer and terminal limits. A locomotive running light in this service will be classed as a road freight train.
3. Coal to be reported on basis of 2000 lbs. per ton, amount to be ascertained by actual weight, measurement, observation, or from statistics of companies showing the consumption of coal on road freight locomotives for given periods and service.
4. The outer station to be given in this report when freight train runs to, from or beyond same is the outermost one shown on the accompanying Official Terminal Map.
5. Local cars have either origin or destination within the city limits. Through cars have neither origin nor destination within the city limits.
6. When actual total tons (2000 lbs.) of road freight train is not known, give estimate of same which covers weight of cars and contents, including caboose.
7. Indicate the route of road freight trains by initials of the roads traveled between terminal and outermost station. If more than one route of the same road, indicate one used.

TRAIN NO.	LOCO. NO.	COAL BURN'D TONS	DEPARTURE		CARS HANDLED			ARRIVAL		ROUTE TRAVELED INITIALS OF ROADS
			STATION OR YARD	TIME	NO.	KIND	TOTAL TONS	STATION OR YARD	TIME	
74	6117	2.06	Morton Grove	5:20A	50 5	LOCAL THRO.	2040 183	Galewood	6:15A	C. M. & St. P.
62	5551	.88	"	7:15A	24 4	LOCAL THRO.	954 168	"	7:50A	"
66	6704	1.74	"	6:15A	45 10	LOCAL THRO.	1863 366	"	7:45A	"
Extra	6711	1.62	"	12:05P	37 16	LOCAL THRO.	1437 645	"	1:00P	"
162	1741	1.06	"	10:25P	34 1	LOCAL THRO.	1344 15	"	11:25P	"
Extra	1934	.74	"	2:10A	24	LOCAL THRO.	954	Western Ave.	3:00A	"
92	2811	.42	Bensenville	6:40P	18 4	LOCAL THRO.	567 60	Galewood	8:00P	"
Extra	6301	.22	"	4:30P	24	LOCAL THRO.	981	Godfrey Yd.	4:50P	"
"	6301	.16	Godfrey Yard	5:30P	9	LOCAL THRO.	351	Galewood	5:50P	"
"	6301	.28	Bensenville	1:38P	31	LOCAL THRO.	1248	Godfrey Yd.	2:15P	"
65	6541	1.87	Western Ave.	9:55P	58	LOCAL THRO.	2402	Morton Grove	11:00P	"
Extra	6117	.48	Galewood	2:40P	22	LOCAL THRO.	612	" "	3:40P	"
"	1917	1.42	"	11:00A	44	LOCAL THRO.	1821	" "	12:15P	"
67	1934	1.82	"	7:10P	57	LOCAL THRO.	2340	" "	8:00P	"
Extra	6543	1.59	"	11:43A	60	LOCAL THRO.	2034	" "	12:35P	"
91	2325	.21	"	5:50A	7	LOCAL THRO.	267	" "	6:50A	"
Extra	6704	1.39	"	2:25P	45	LOCAL THRO.	1782	" "	4:30P	"
2/63	3100	2.08	"	5:20A	64	LOCAL THRO.	2667	" "	6:00A	"
65	1606	.66	"	11:02P	24	LOCAL THRO.	981	Bensenville	11:35P	"
Extra	2802	1.12	"	9:30P	40	LOCAL THRO.	1653	"	9:55P	"
"	2801	.81	"	1:10P	31	LOCAL THRO.	1194	"	1:35P	"
"	2449	.36	"	1:25P	1	LOCAL THRO.	15	Western Ave.	2:00P	"
"	2449	1.11	Western Ave.	3:30P	64	LOCAL THRO.	987	Bensenville	5:10P	"
"	6703	1.24	Morton Grove	1:25A	26 17	LOCAL THRO.	984 606	Galewood	3:25A	"

FIG. 392. TYPICAL REPORT OF ROAD FREIGHT TRAIN MOVEMENTS ("FORM 2")



F. 103. 6-24-12 2M

The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals

122 MICHIGAN BOULEVARD, CHICAGO

FORM 3.

CHICAGO TERMINAL

C. B. & Q. Ry.

Date, Ending Midnight August 13, 1912

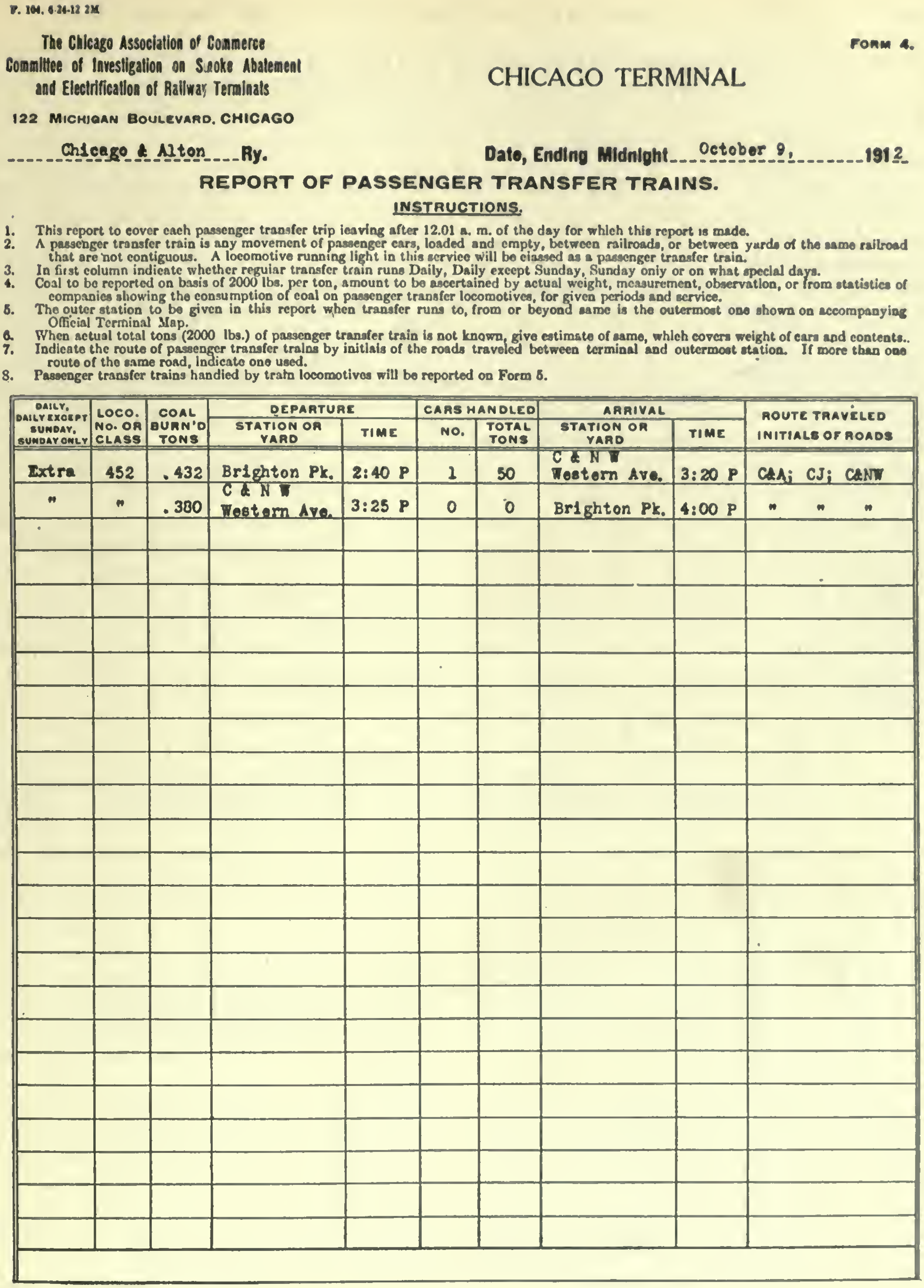
REPORT OF FREIGHT TRANSFER TRAINS.

INSTRUCTIONS.

1. This report to cover each freight transfer trip leaving after 12.01 a. m. of the day for which this report is made.
2. A freight transfer train is any movement of freight cars, loaded and empty, between railroads, or between yards of the same railroad that are not contiguous. A locomotive running light in this service will be classed as a freight transfer train.
3. Coal to be reported on basis of 2000 lbs. per ton, amount to be ascertained by actual weight, measurement, observation, or from statistics of companies showing the consumption of coal on freight transfer locomotives for given periods and service.
4. The outer station to be given in this report when transfer runs to, from or beyond same is the outermost one shown on the accompanying Official Terminal Map.
5. Local cars have either origin or destination within the city limits. Through cars have neither origin nor destination within the city limits.
6. When actual total tons (2000 lbs.) of freight transfer train is not known, give estimate of same which covers weight of cars and contents, including caboose.
7. Indicate the route of freight transfer trains by initials of the roads traveled between terminal and outermost station. If more than one route of the same road, indicate one used.

LOCO. No. OR CLASS	COAL BURN'D TONS	DEPARTURE		CARS HANDLED			ARRIVAL		ROUTE TRAVELED INITIALS OF ROADS
		STATION OR YARD	TIME	NO.	KIND	TOTAL TONS	STATION OR YARD	TIME	
1690	.254	Western Ave.	5:15 A	26	LOCAL	1020	Harrison St.	6:10 A	C. B. & Q.
					THRO.				
1690	.116	Harrison St.	7:00 A		LOCAL		Western Ave.	7:25 A	"
					THRO.				
1690	.069	Western Ave.	7:45 A		LOCAL		Canal St.	8:00 A	"
					THRO.				
1690	.046	Canal St.	8:25 A	8	LOCAL	180	Harrison St.	8:35 A	"
					THRO.				
1690	.209	Canal St.	5:45 P	7	LOCAL	215	Western Ave.	6:30 P	"
					THRO.				
1690	.092	Western Ave.	7:20 P		LOCAL		Canal St.	7:40 P	"
					THRO.				
1690	.069	Canal St.	8:45 P		LOCAL		14th St.	9:00 P	"
					THRO.				
1690	.023	14th St.	10:00 P		LOCAL		Harrison St.	10:05 P	"
					THRO.				
1690	.028	PFW&C 18th St.	10:15 P		LOCAL		Canal St.	10:22 P	P. F. W. & C.-Q
					THRO.				
1415	.137	Western Ave.	3:50 A	42	LOCAL	1850	Lumber Dist.	4:20 A	Sangamon St.
					THRO.				
1415	.065	Lumber Dist.	7:10 A		LOCAL		Western Ave.	7:25 A	" "
					THRO.				
1415	.297	Western Ave.	8:25 A	30	LOCAL	1350	Canal St.	9:30 A	C. B. & Q.
					THRO.				
1415	.065	Canal St.	9:30 A		LOCAL		Western Ave.	9:45 A	"
					THRO.				
1415	.065	Canal St.	2:50 P	7	LOCAL	315	Harrison St.	3:05 P	"
					THRO.				
1415	.045	Harrison St.	3:25 P		LOCAL		Canal St.	3:35 P	"
					THRO.				
1415	.090	Canal St.	3:35 P	8	LOCAL	285	Western Ave.	3:55 P	"
					THRO.				
1415	.090	Western Ave.	4:45 P	17	LOCAL	765	Hawthorne Yd	5:05 P	"
					THRO.				
1415	.137	Western Ave.	7:30 P		LOCAL		Lumber Dist.	8:00 P	26th St.
					THRO.				
1415	.297	Lumber Dist.	11:05 A	50	LOCAL	2200	Western Ave.	12:10 P	"
					THRO.				
1419	.137	Western Ave.	7:10 P		LOCAL		Lumber Dist.	7:40 P	"
					THRO.				
3185	.187	Belt Hawthorne	9:35 A		LOCAL		Hawthorne Yd	10:00 A	Belt - CB&Q
					THRO.				
3185	.487	Hawthorne Yd	10:55 A	17	LOCAL	691	PCC&StL 47th St.	12:00 A	C. B. &Q-PCC&StL
				3	THRO.	95			
3185	.471	PCC&St. L 47th St.	12:00 A	1	LOCAL	10	Hawthorne Yd	1:05 P	PCC&StL-CB&Q
					THRO.				
					LOCAL				
					THRO.				

FIG. 393. TYPICAL REPORT OF FREIGHT TRANSFER TRAIN MOVEMENTS ("FORM 3")



F. 104. 6-24-12 2M

The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals

122 Michigan Boulevard, Chicago

Form 4.

CHICAGO TERMINAL

Chicago & Alton Ry.

Date, Ending Midnight October 9, 1912

REPORT OF PASSENGER TRANSFER TRAINS.

INSTRUCTIONS.

1. This report to cover each passenger transfer trip leaving after 12.01 a. m. of the day for which this report is made.
2. A passenger transfer train is any movement of passenger cars, loaded and empty, between railroads, or between yards of the same railroad that are not contiguous. A locomotive running light in this service will be classed as a passenger transfer train.
3. In first column indicate whether regular transfer train runs Daily, Daily except Sunday, Sunday only or on what special days.
4. Coal to be reported on basis of 2000 lbs. per ton, amount to be ascertained by actual weight, measurement, observation, or from statistics of companies showing the consumption of coal on passenger transfer locomotives, for given periods and service.
5. The outer station to be given in this report when transfer runs to, from or beyond same is the outermost one shown on accompanying Official Terminal Map.
6. When actual total tons (2000 lbs.) of passenger transfer train is not known, give estimate of same, which covers weight of cars and contents..
7. Indicate the route of passenger transfer trains by initials of the roads traveled between terminal and outermost station. If more than one route of the same road, indicate one used.
8. Passenger transfer trains handled by train locomotives will be reported on Form 5.

Daily, Daily except Sunday, Sunday only	Loco. No. or Class	Coal Burn'd Tons	Departure		Cars Handled		Arrival		Route Traveled Initials of Roads
			Station or Yard	Time	No.	Total Tons	Station or Yard	Time	
Extra	452	.432	Brighton Pk.	2:40 P	1	50	C & N W Western Ave.	3:20 P	C&A; CJ; C&NW
"	"	.380	C & N W Western Ave.	3:25 P	0	0	Brighton Pk.	4:00 P	" " "

FIG. 394. TYPICAL REPORT OF PASSENGER TRANSFER TRAIN MOVEMENTS ("FORM 4")
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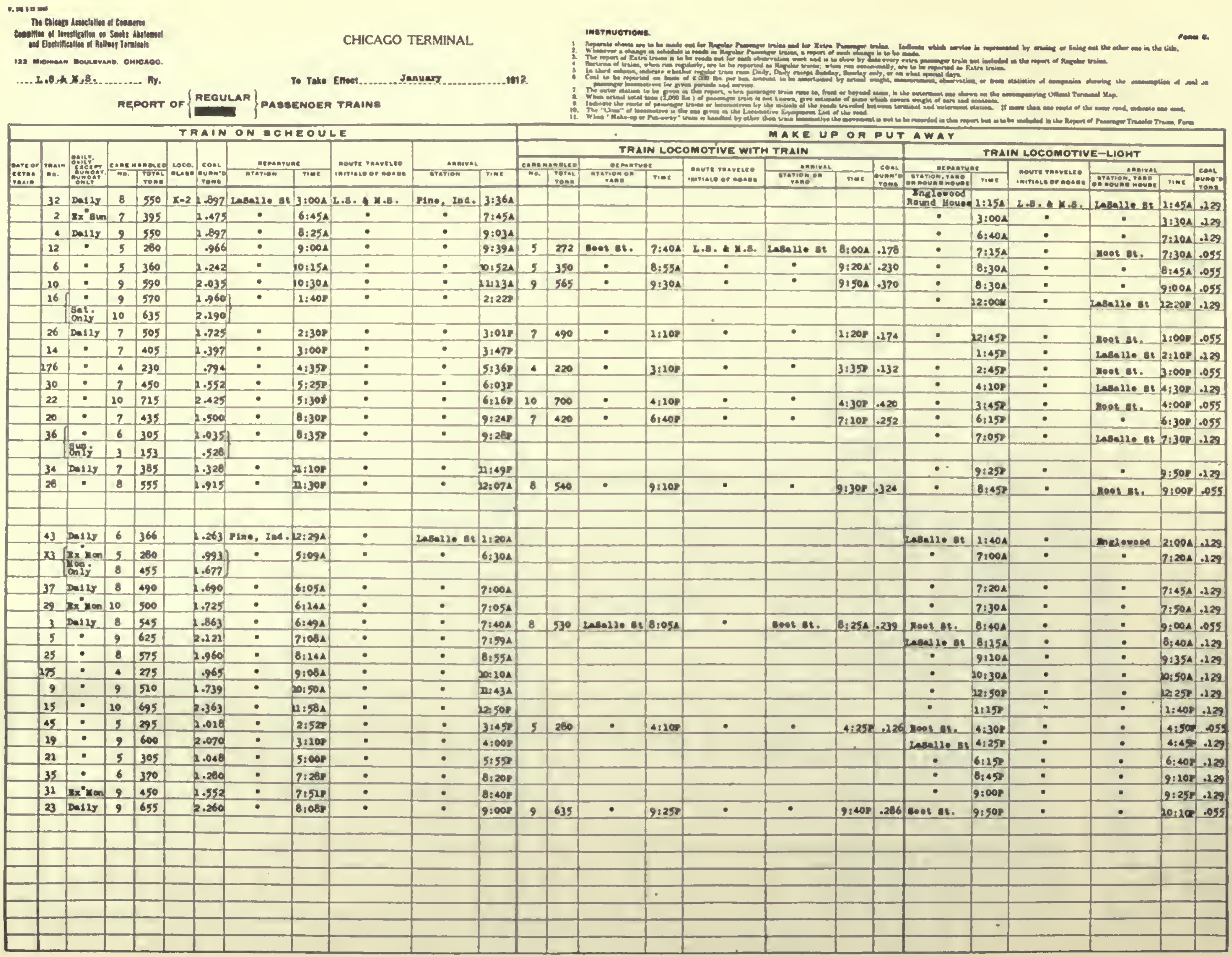

F. 395 3-12 1000

The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals

122 Michigan Boulevard, Chicago.

CHICAGO TERMINAL

....L.S.& M.S.............. Ry.

To Take Effect..........January..................1912.

REPORT OF { REGULAR / [redacted] } PASSENGER TRAINS

INSTRUCTIONS. Form 5.

1. Separate sheets are to be made out for Regular Passenger trains and for Extra Passenger trains. Indicate which service is represented by erasing or lining out the other one in the title.
2. Whenever a change in schedule is made in Regular Passenger trains, a report of such change is to be made.
3. The report of Extra trains is to be made out for each observation week and is to show by date every extra passenger train not included in the report of Regular trains.
4. Sections of trains, when run regularly, are to be reported as Regular trains; when run occasionally, are to be reported as Extra trains.
5. In third column, indicate whether regular train runs Daily, Daily except Sunday, Sunday only, or on what special days.
6. Coal to be reported on basis of 2,000 lbs. per ton, amount to be ascertained by actual weight, measurement, observation, or from statistics of companies showing the consumption of coal on passenger locomotives for given periods and service.
7. The outer station to be given in this report, when passenger train runs to, from or beyond same, is the outermost one shown on the accompanying Official Terminal Map.
8. When actual total tons (2,000 lbs.) of passenger train is not known, give estimate of same which covers weight of cars and contents.
9. Indicate the route of passenger trains or locomotives by the initials of the roads traveled between terminal and outermost station. If more than one route of the same road, indicate one used.
10. The "Class" of locomotive is the one given in the Locomotive Equipment List of the road.
11. When "Make-up or Put-away" train is handled by other than train locomotive the movement is not to be recorded in this report but is to be included in the Report of Passenger Transfer Trains, Form

TRAIN ON SCHEDULE												MAKE UP OR PUT AWAY													
												TRAIN LOCOMOTIVE WITH TRAIN								TRAIN LOCOMOTIVE—LIGHT					
Date of Extra Train	Train No.	Daily, Daily Except Sunday, Sunday Only	Cars Handled		Loco. Class	Coal Burn'd Tons	Departure		Route Traveled	Arrival		Cars Handled		Departure		Route Traveled	Arrival		Coal Burn'd Tons	Departure		Route Traveled	Arrival		Coal Burn'd Tons
			No.	Total Tons			Station	Time	Initials of Roads	Station	Time	No.	Total Tons	Station or Yard	Time	Initials of Roads	Station or Yard	Time		Station, Yard or Round House	Time	Initials of Roads	Station, Yard or Round House	Time	
	32	Daily	8	550	K-2	1.897	LaSalle St	3:00A	L.S. & M.S.	Pine, Ind.	3:36A									Englewood Round House	1:15A	L.S. & M.S.	LaSalle St	1:45A	.129
	2	Ex Sun	7	395		1.475	•	6:45A	•	•	7:45A									•	3:00A	•	•	3:30A	.129
	4	Daily	9	550		1.897	•	8:25A	•	•	9:03A									•	6:40A	•	•	7:10A	.129
	12	•	5	280		.966	•	9:00A	•	•	9:39A	5	272	Root St.	7:40A	L.S. & M.S.	LaSalle St	8:00A	.178	•	7:15A	•	Root St.	7:30A	.055
	6	•	5	360		1.242	•	10:15A	•	•	10:52A	5	350	•	8:55A	•	•	9:20A	.230	•	8:30A	•	•	8:45A	.055
	10	•	9	590		2.035	•	10:30A	•	•	11:13A	9	565	•	9:30A	•	•	9:50A	.370	•	8:30A	•	•	9:00A	.055
	16	•	9	570		1.960	•	1:40P	•	•	2:22P									•	12:00M	•	LaSalle St	12:20P	.129
		Sat. Only	10	635		2.190																			
	26	Daily	7	505		1.725	•	2:30P	•	•	3:01P	7	490	•	1:10P	•	•	1:20P	.174	•	12:45P	•	Root St.	1:00P	.055
	14	•	7	405		1.397	•	3:00P	•	•	3:47P										1:45P	•	LaSalle St	2:10P	.129
	176	•	4	230		.794	•	4:35P	•	•	5:36P	4	220	•	3:10P	•	•	3:35P	.132	•	2:45P	•	Root St.	3:00P	.055
	30	•	7	450		1.552	•	5:25P	•	•	6:03P									•	4:10P	•	LaSalle St	4:30P	.129
	22	•	10	715		2.425	•	5:30P	•	•	6:16P	10	700	•	4:10P	•	•	4:30P	.420	•	3:45P	•	Root St.	4:00P	.055
	20	•	7	435		1.500	•	8:30P	•	•	9:24P	7	420	•	6:40P	•	•	7:10P	.252	•	6:15P	•	•	6:30P	.055
	36	•	6	305		1.035	•	8:35P	•	•	9:28P									•	7:05P	•	LaSalle St	7:30P	.129
		Sun. Only	3	153		.528																			
	34	Daily	7	385		1.328	•	11:10P	•	•	11:49P									•	9:25P	•	•	9:50P	.129
	28	•	8	555		1.915	•	11:30P	•	•	12:07A	8	540	•	9:10P	•	•	9:30P	.324	•	8:45P	•	Root St.	9:00P	.055
	43	Daily	6	366		1.263	Pine, Ind.	12:29A	•	LaSalle St	1:20A									LaSalle St	1:40A	•	Englewood	2:00A	.129
	X3	Ex Mon	5	280		.993	•	5:09A	•	•	6:30A									•	7:00A	•	•	7:20A	.129
		Mon. Only	8	455		1.677																			
	37	Daily	8	490		1.690	•	6:05A	•	•	7:00A									•	7:20A	•	•	7:45A	.129
	29	Ex Mon	10	500		1.725	•	6:14A	•	•	7:05A									•	7:30A	•	•	7:50A	.129
	3	Daily	8	545		1.863	•	6:49A	•	•	7:40A	8	530	LaSalle St	8:05A	•	Root St.	8:25A	.239	Root St.	8:40A	•	•	9:00A	.055
	5	•	9	625		2.121	•	7:08A	•	•	7:59A									LaSalle St	8:15A	•	•	8:40A	.129
	25	•	8	575		1.960	•	8:14A	•	•	8:55A									•	9:10A	•	•	9:35A	.129
	175	•	4	275		.965	•	9:08A	•	•	10:10A									•	10:30A	•	•	10:50A	.129
	9	•	9	510		1.739	•	10:50A	•	•	11:43A									•	12:50P	•	•	12:25P	.129
	15	•	10	695		2.363	•	11:58A	•	•	12:50P									•	1:15P	•	•	1:40P	.129
	45	•	5	295		1.018	•	2:52P	•	•	3:45P	5	280	•	4:10P	•	•	4:25P	.126	Root St.	4:30P	•	•	4:50P	.055
	19	•	9	600		2.070	•	3:10P	•	•	4:00P									LaSalle St	4:25P	•	•	4:45P	.129
	21	•	5	305		1.048	•	5:00P	•	•	5:55P									•	6:15P	•	•	6:40P	.129
	35	•	6	370		1.280	•	7:28P	•	•	8:20P									•	8:45P	•	•	9:10P	.129
	31	Ex Mon	9	450		1.552	•	7:51P	•	•	8:40P									•	9:00P	•	•	9:25P	.129
	23	Daily	9	655		2.260	•	8:08P	•	•	9:00P	9	635	•	9:25P	•	•	9:40P	.286	Root St.	9:50P	•	•	10:10P	.055

FIG. 395. TYPICAL REPORT OF PASSENGER TRAIN MOVEMENTS ("FORM 5")

summarized only by final results, is suggested by the fact that, in addition to the engineering and clerical staff of the Committee, the work required the services of several employes on each railroad for the greater part of a year.

202.03 The Uses of the Report Forms: The forms called for information covering activities within the entire Area of Investigation. Accompanying the blanks sent to the railroads were a map on which the limits of the Area of Investigation were defined, and a list of the outermost stations on each road with their distances from the city limits and from the city passenger terminal used by the road in question. Those railroads which are entirely within the Area of Investigation were requested to report all movements and, if operating beyond the limits over the tracks of another railroad, to be governed by the outermost station as given for that road. On the map the limiting line was drawn just beyond the outermost station as given in the statement, but the station was taken as the limit. In cases where this station lay within a yard, directions were given that the reports on "Form 1" (fig. 391) should include the work in the entire yard, even though part of the yard might lie beyond the outermost station.

With reference to the amount of coal consumed, all forms required that it be obtained either by weighing or measuring, or from statistics of the companies showing the consumption of coal for given periods by locomotives engaged in similar service; but, in the discussion between members of the engineering staff of the Committee and representatives of railroads, many views were expressed as to the advisability of reporting the fuel on an hourly or mileage basis and also as to the simplest and most accurate method of obtaining this record. A meeting was held at which representatives of more than 20 of the railroads operating within the Area of Investigation joined with the Committee's engineering staff for a discussion of the matter. At this meeting a committee representing 14 railroads was appointed to formulate a definite plan. The report of this committee recommended that the actual amount of coal issued to suburban, switching, work and transfer locomotives be accounted for on either an hourly or a mileage basis, and that the coal issued to passenger and freight locomotives in through service be ascertained and accounted for on a mileage basis for the division running into Chicago.* This suggestion, however, was not uniformly followed by all roads.

"Form 1" (fig. 391) was used for reporting movements involving both passenger and freight switching for each day of 24 hours, commencing at 12:01 A.M. of the day on which the report was dated. It was used also in reporting movements of locomotives employed in industrial or other terminal switching service not included in the reports of transfer service.

"Form 2" (fig. 392) was used in reporting the movements of all outbound road freight trains leaving the terminal, and of all inbound road freight trains leaving the outermost station within the defined limits, on the day covered by the report. A road freight train was defined as one handling freight cars, loaded or empty, between points inside and points outside of the transfer and terminal limits. Locomotives running light in this service were also included. Local cars were defined as those having either origin or destination within the city limits, and through cars as those shipped from points outside the city and consigned to points outside the city. Through cars which appear in the Chicago terminals are, of course, in transit between their origin and destination. When it was not possible to distinguish accurately between through and local empty cars, they were pro-rated on the basis of the through and local loaded cars in the same train.

"Form 3" (fig. 393) was used in reporting the movements of freight transfer trains, which were defined as trains made up of freight cars, loaded or empty, in transit between different railroads or between yards of the same railroad that are not contiguous. Locomotives running light in this service were also included.

"Form 4" (fig. 394) was used in reporting the movements of passenger transfer trains, which were defined as trains made up of passenger cars, loaded or empty, in transit between different railroads or between yards of the same railroad that are not contiguous. Locomotives running light in this service were also included, but passenger transfer trains handled by train locomotives were reported as passenger trains on "Form 5."

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* See letter of R. Quayle, Chairman, dated Nov. 20, 1911, Archives of the Committee, Vol. D.

"Form 5" (fig. 395) was used in reporting the movements of regular and extra passenger trains. Sections of trains, when run regularly, were reported as regular trains; when run occasionally, as extra trains.

In the reports on all of the forms except that for yard switching, each railroad reported the number of cars handled and the routes traveled by its own locomotives, whether using its own tracks or the tracks of another railroad.

202.04 Report Periods: It was the original intention to secure full reports on each of the forms, covering a period of one week during each month of the year 1912. Owing, however, to the magnitude of the work devolving upon the railroads, to the probability that the work of one month's observation period would overlap that of the next, to the difficulty of exercising such supervision as would insure uniformity, accuracy and completeness in the reports from so large a number of observers and from so many localities, and to the vast number of facts that were being developed on the completed forms, it was decided to reduce the number of report periods but, at the same time, to distribute them over the entire year in a manner which would render the result fully representative. The observation periods selected and covered by the reports were as follows:

Week of January 9–15, inclusive.
Week of March 12–18, inclusive.
Week of May 14–20, inclusive.
Week of August 13–19, inclusive.
Week of October 8–14, inclusive.

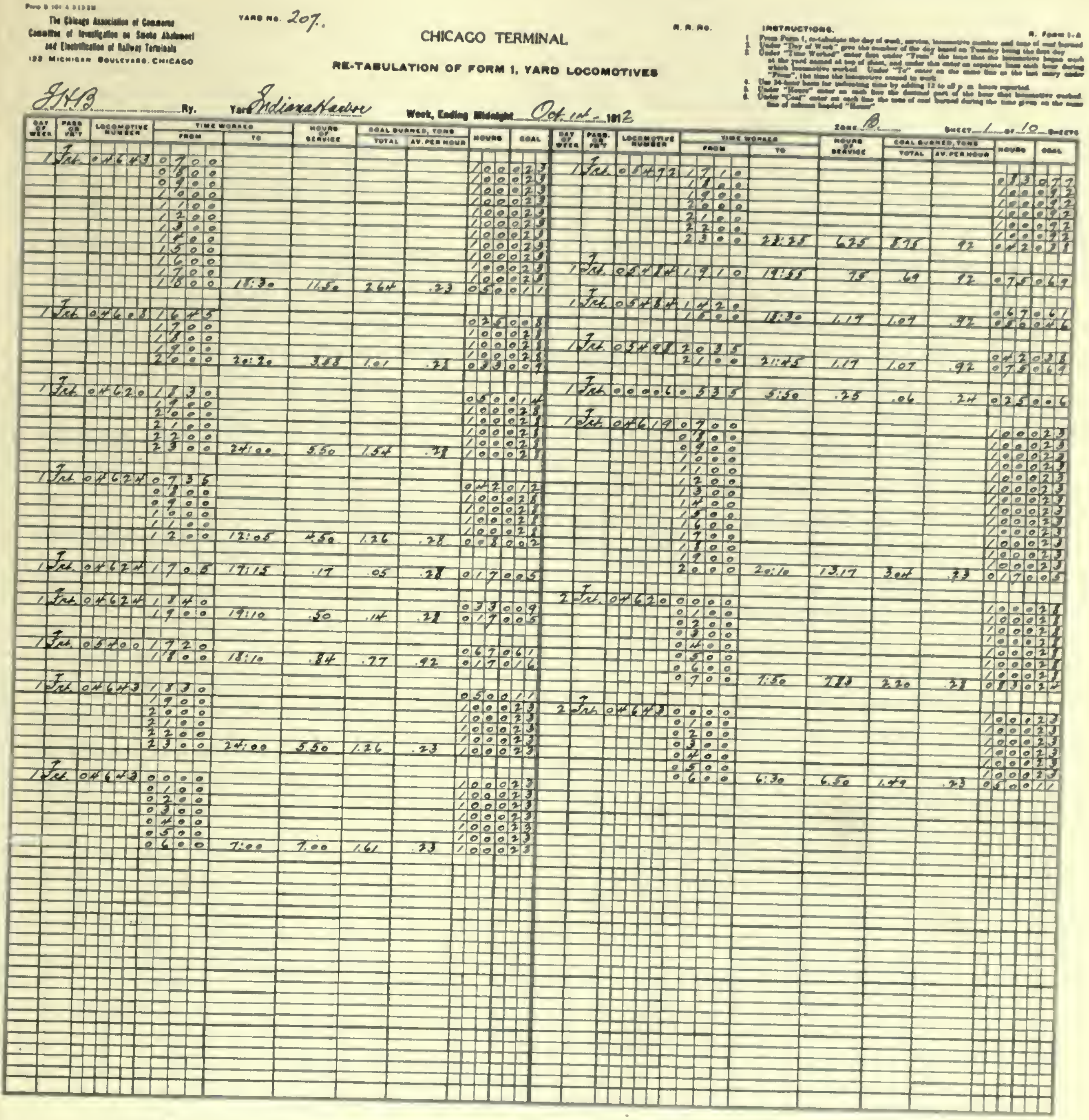
202.05 Retabulation of Reported Data: Information received from the railroads on "Form 1" (fig. 391) was retabulated on "Form 1-A" (fig. 396), and the information received on Forms 2, 3, 4 and 5 (figs. 392 to 395, inclusive,) was retabulated on "Form 2345-A" (fig. 397).

The calculations necessary to subdivide the information reported by the railroads into the hourly data required in the case of the reports of yard switching service submitted on "Form 1" and into "elements" in the case of information reported on other forms, were made on the retabulation sheets "Form 1-A" and "Form 2345-A" (figs. 396 and 397). For example, under the heading "Day of Week" on "Form 1-A," was given the number of the day, Tuesday being taken as the first day of the observation period. The entries under character of service, "Passenger or Freight," and under "Locomotive Number" require no explanation. Under the heading "Time Worked" was entered first, under "From," at the top of the sheet, the time that the locomotive began work at the yard named, and under this, each on a separate line, was entered each hour during which the locomotive worked, the 24-hour basis being introduced by the addition of 12 to all P.M. hours entered; under "To" was entered on the same line as the last entry under "From," the hour when the locomotive ceased to work. Under "Hours of Service" was entered in decimal form the number of hours the locomotive worked; under "Hours" was entered the hour or decimal corresponding to each entry under "Time Worked"; under "Coal" were made entries showing the amount of coal consumed in each hour and fraction of an hour as deduced from the column, "Coal Burned, Tons," and its subdivisions, "Total" and "Average per Hour." Each entry on "Form 1-A" was made to cover a period of one hour or fraction thereof. The work covered by the first entry illustrated in fig. 396, having required 5.5 hours, the statement of facts is subdivided into six entries.

The retabulation required the use of the official route map, which has been elsewhere described (section 104.05), in order that the names given in the railroad reports might be translated into location or "element" numbers as shown on the route map.

With the completion of this retabulation the information contained upon the sheets was transferred to cards of the Hollerith system (section 202.07) by means of which the facts could be tabulated according to any desired arrangement.

202.06 Field Tests and Observations: A large number of field tests and observations were made in each class of service to obtain supplementary information needed for subsequent calculations and to provide a basis for checking the information contained in the reports. These tests were conducted jointly by a representative of the railroads and a representative of the Committee. A form prepared by the Committee was employed for entering the facts observed. A reproduction of this form, upon which is entered a typical record of a test, is presented as fig. 398.



The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals
123 Michigan Boulevard, Chicago

YARD No. 207.

R. R. No.

CHICAGO TERMINAL

RE-TABULATION OF FORM 1, YARD LOCOMOTIVES

INSTRUCTIONS.

R. Form 1-A

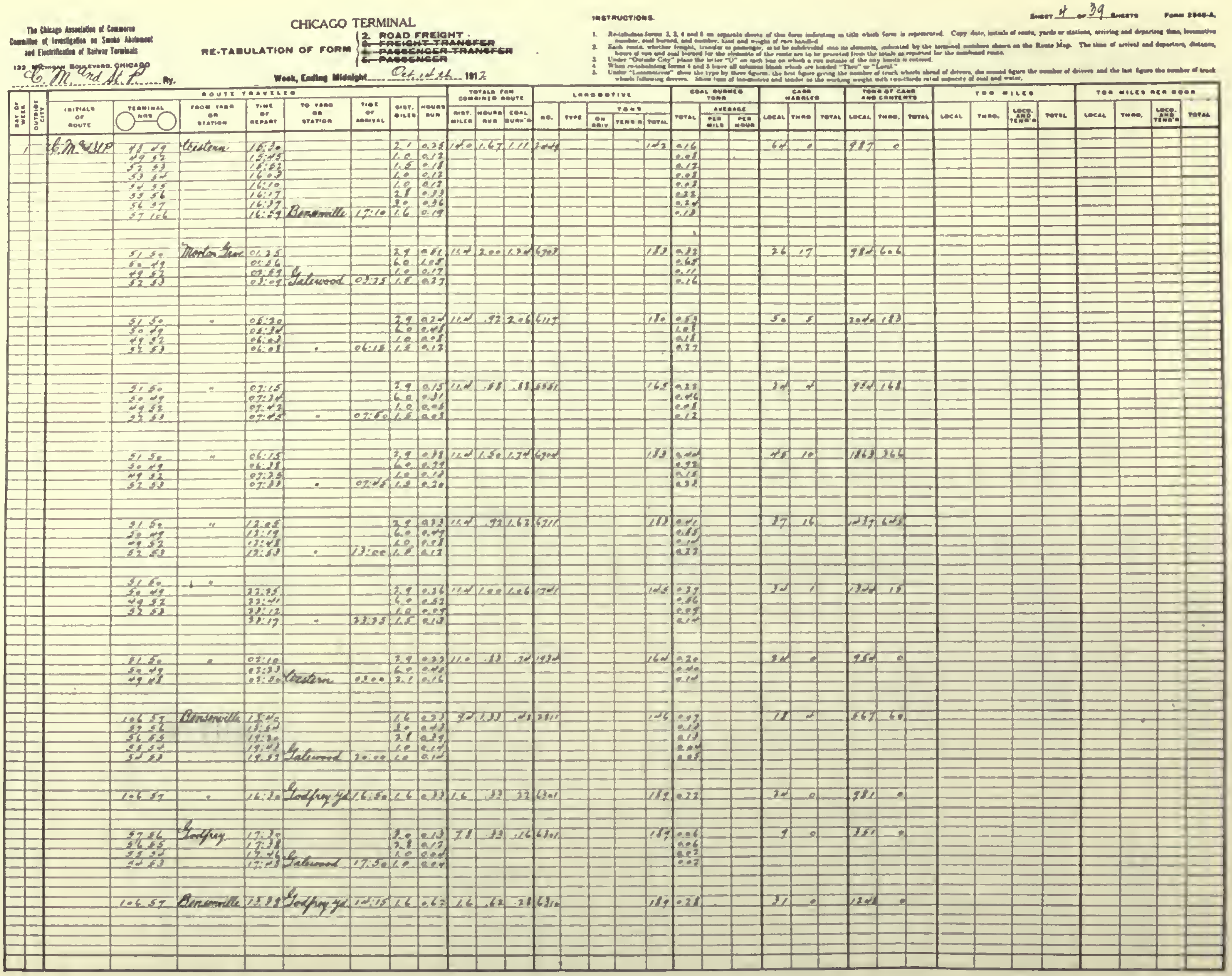
IHB Ry. Yard Indiana Harbor Week, Ending Midnight Oct. 1st - 1912

Zone B. Sheet 1 of 10 Sheets

Day of Week	Pass. or Fr't	Locomotive Number	Time Worked		Hours of Service	Coal Burned, Tons		Hours	Coal
			From	To		Total	Av. per Hour		
1	Frt.	04643	0700					100	023
			0800					100	023
			0900					100	023
			1000					100	023
			1100					100	023
			1200					100	023
			1300					100	023
			1400					100	023
			1500					100	023
			1600					100	023
			1700					100	023
			1800	18:30	11.50	2.64	.23	050	011
1	Frt.	04608	1645					025	008
			1700					100	028
			1800					100	028
			1900					100	028
			2000	20:20	3.58	1.01	.28	033	009
1	Frt.	04620	1830					050	014
			1900					100	028
			2000					100	028
			2100					100	028
			2200					100	028
			2300	24:00	5.50	1.54	.28	100	028
1	Frt.	04624	0735					042	012
			0800					100	028
			0900					100	028
			1000					100	028
			1100					100	028
			1200	12:05	4.50	1.26	.28	008	002
1	Frt.	04624	1705	17:15	.17	.05	.28	017	005
1	Frt.	04624	1840					033	009
			1900	19:10	.50	.14	.28	017	005
1	Frt.	05400	1720					067	061
			1800	18:10	.84	.77	.92	017	016
1	Frt.	04643	1830					050	011
			1900					100	023
			2000					100	023
			2100					100	023
			2200					100	023
			2300	24:00	5.50	1.26	.23	100	023
1	Frt.	04643	0000					100	023
			0100					100	023
			0200					100	023
			0300					100	023
			0400					100	023
			0500					100	023
			0600	7:00	7.00	1.61	.23	100	023

Day of Week	Pass. or Fr't	Locomotive Number	Time Worked		Hours of Service	Coal Burned, Tons		Hours	Coal
			From	To		Total	Av. per Hour		
1	Frt.	05472	1710					083	077
			1800					100	092
			1900					100	092
			2000					100	092
			2100					100	092
			2200					100	092
			2300	23:25	6.25	5.75	.92	042	038
1	Frt.	05484	1910	19:55	.75	.69	.92	075	069
1	Frt.	05484	1420					067	061
			1500	15:30	1.17	1.07	.92	050	046
1	Frt.	05498	2035					042	038
			2100	21:45	1.17	1.07	.92	075	069
1	Frt.	00006	0535	5:50	.25	.06	.24	025	006
1	Frt.	04619	0700					100	023
			0800					100	023
			0900					100	023
			1000					100	023
			1100					100	023
			1200					100	023
			1300					100	023
			1400					100	023
			1500					100	023
			1600					100	023
			1700					100	023
			1800					100	023
			1900					100	023
			2000	20:10	13.17	3.04	.23	017	005
2	Frt.	04620	0000					100	028
			0100					100	028
			0200					100	028
			0300					100	028
			0400					100	028
			0500					100	028
			0600					100	028
			0700	7:50	7.83	2.20	.28	083	024
2	Frt.	04643	0000					100	023
			0100					100	023
			0200					100	023
			0300					100	023
			0400					100	023
			0500					100	023
			0600	6:30	6.50	1.49	.23	050	011

FIG. 396. RETABULATION FORM FOR REPORTS OF YARD LOCOMOTIVE MOVEMENTS ("FORM 1-A")



The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals
132 Michigan Boulevard, Chicago

C. M. and St. P. Ry.

CHICAGO TERMINAL

RE-TABULATION OF FORM
2. ROAD FREIGHT
~~3. FREIGHT TRANSFER~~
~~4. PASSENGER TRANSFER~~
~~5. PASSENGER~~

Week, Ending Midnight Oct. 14th 1912

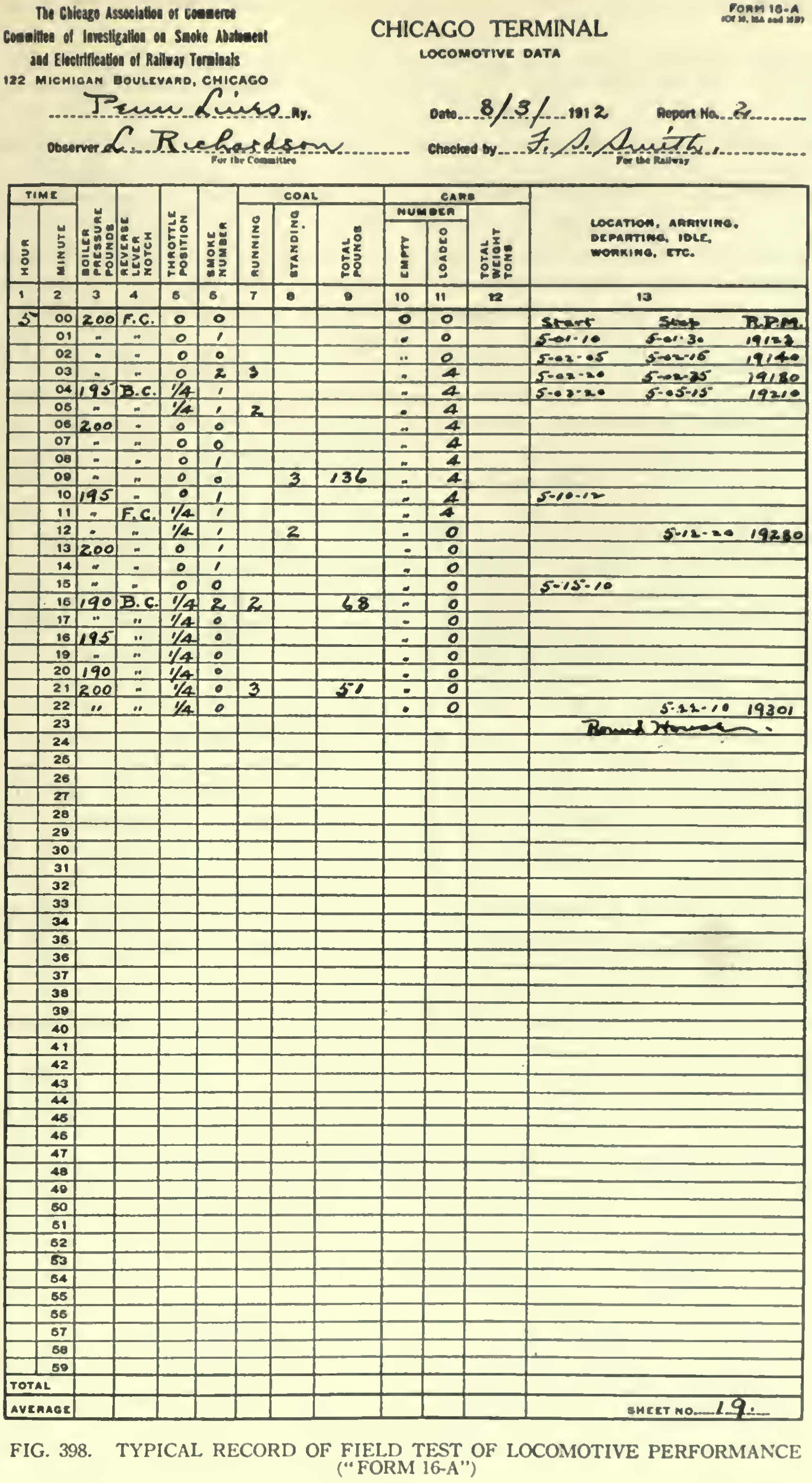
INSTRUCTIONS.

1. Re-tabulate forms 2, 3, 4 and 5 on separate sheets of this form indicating in title which form is represented. Copy date, initials of route, yards or stations, arriving and departing time, locomotive number, coal burned, and number, kind and weight of cars handled.
2. Each route, whether freight, transfer or passenger, is to be subdivided into its elements, indicated by the terminal numbers shown on the Route Map. The time of arrival and departure, distance, hours of run and coal burned for the elements of the route are to be prorated from the totals as reported for the combined route.
3. Under "Outside City" place the letter "O" on each line on which a run outside of the city limits is entered.
4. When re-tabulating forms 4 and 5 leave all columns blank which are headed "Thro" or "Local."
5. Under "Locomotive" show the type by three figures, the first figure giving the number of truck wheels ahead of drivers, the second figure the number of drivers and the last figure the number of truck wheels following drivers. Show tons of locomotive and tender as the working weight with two-thirds rated capacity of coal and water.

Sheet 4 of 39 Sheets Form 2345-A.

Day of Week	Outside City	Route Traveled: Initials of Route	Terminal Nos.	From Yard or Station	Time of Depart	To Yard or Station	Time of Arrival	Dist. Miles	Hours Run	Totals for Combined Route: Dist. Miles	Hours Run	Coal Burn'd	Locomotive: No.	Type	Tons: On Driv	Tend'r	Total	Coal Burned Tons: Total	Average: Per Mile	Per Hour	Cars Handled: Local	Thro	Total	Tons of Cars and Contents: Local	Thro.	Total	Ton Miles: Local	Thro.	Loco. and Tend'r	Total	Ton Miles per Hour: Local	Thro.	Loco. and Tend'r	Total
1		C. M. & St. P.	48 49	Western	15:30			2.1	0.26	14.0	1.67	1.11	2044				142	0.16			64	0		987	0									
			49 52		15:45			1.0	0.13									0.08																
			52 53		15:53			1.5	0.18									0.17																
			53 54		16:03			1.0	0.13									0.08																
			54 55		16:10			1.0	0.13									0.08																
			55 56		16:17			2.8	0.33									0.22																
			56 57		16:37			3.0	0.36									0.24																
			57 106		16:59	Bensenville	17:10	1.6	0.19									0.13																
			51 50	Morton Grove	01:35			2.9	0.61	11.4	2.00	1.34	6708				183	0.32			26	17		984	606									
			50 49		01:56			6.0	1.05									0.65																
			49 52		02:59			1.0	0.17									0.11																
			52 53		03:09	Galewood	03:35	1.5	0.27									0.26																
			51 50	"	05:30			2.9	0.34	11.4	.92	2.06	6117				180	0.59			50	5		2040	183									
			50 49		05:34			6.0	0.48									1.08																
			49 52		06:03			1.0	0.08									0.18																
			52 53		06:08	"	06:18	1.5	0.13									0.32																
			51 50	"	07:15			2.9	0.15	11.4	.58	.88	6551				165	0.23			24	4		954	168									
			50 49		07:34			6.0	0.31									0.46																
			49 52		07:42			1.0	0.06									0.08																
			52 53		07:45	"	07:50	1.5	0.03									0.12																
			51 50	"	06:15			2.9	0.38	11.4	1.50	1.34	6304				183	0.44			45	10		1863	364									
			50 49		06:38			6.0	0.39									0.42																
			49 52		07:35			1.0	0.18									0.16																
			52 53		07:39	"	07:45	1.5	0.20									0.32																
			51 50	"	12:05			2.9	0.33	11.4	.92	1.63	6211				182	0.41			37	16		1237	645									
			50 49		12:19			6.0	0.47									0.85																
			49 52		12:48			1.0	0.08									0.14																
			52 53		12:53	"	13:00	1.5	0.12									0.23																
			51 50	"																														
			50 49		22:25			2.9	0.36	11.4	1.00	1.66	1704				145	0.37			32	1		1304	15									
			49 52		22:40			6.0	0.52									0.56																
			52 53		23:12			1.0	0.05									0.09																
					23:17	"	23:25	1.5	0.13									0.14																
			51 50	"	03:10			2.9	0.33	11.0	.88	.94	1934				164	0.20			34	0		954	0									
			50 49		03:33			6.0	0.48									0.40																
			49 48		03:50	Western	04:00	2.1	0.16									0.14																
			106 57	Bensenville	18:40			1.6	0.23	9.4	1.33	.43	2811				126	0.07			18	4		867	60									
			57 56		18:54			3.0	0.48									0.12																
			56 55		19:30			2.8	0.39									0.13																
			55 54		19:42			1.0	0.14									0.04																
			54 53		19:53	Galewood	20:00	1.0	0.14									0.05																
			106 57	"	16:30	Godfrey Yd.	16:50	1.6	0.33	1.6	.33	.22	6301				189	0.22			34	0		981	0									
			57 56	Godfrey	17:30			3.0	0.13	7.8	.33	.16	6301				189	0.06			9	0		251	0									
			56 55		17:38			2.8	0.17									0.06																
			55 54		17:46			1.0	0.04									0.02																
			54 53		17:48	Galewood	17:50	1.0	0.04									0.02																
			106 57	Bensenville	15:38	Godfrey Yd.	16:15	1.6	0.62	1.6	.62	.28	6310				189	0.28			31	0		1244	0									

FIG. 397. RETABULATION FORM FOR REPORTS OF ALL TRAIN AND LOCOMOTIVE MOVEMENTS EXCEPT YARD SERVICE ("FORM 2345-A")



The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals
122 Michigan Boulevard, Chicago

CHICAGO TERMINAL
LOCOMOTIVE DATA

FORM 16-A
(Of 16, 16A and 16B)

Penn Lines Ry.

Date 8/31/ 1912 Report No. 2

Observer L. Richardson
For the Committee

Checked by F. S. Smith.
For the Railway

TIME						COAL			CARS			
									NUMBER			
HOUR	MINUTE	BOILER PRESSURE POUNDS	REVERSE LEVER NOTCH	THROTTLE POSITION	SMOKE NUMBER	RUNNING	STANDING	TOTAL POUNDS	EMPTY	LOADED	TOTAL WEIGHT TONS	LOCATION, ARRIVING, DEPARTING, IDLE, WORKING, ETC.
1	2	3	4	5	6	7	8	9	10	11	12	13
5	00	200	F.C.	0	0				0	0		Start Stop R.P.M.
	01	"	"	0	1				"	0		5-01-10 5-01-30 19122
	02	"	"	0	0				"	0		5-02-05 5-02-16 19140
	03	"	"	0	2	3			"	4		5-02-20 5-02-35 19180
	04	195	B.C.	1/4	1				"	4		5-03-20 5-05-15 19210
	05	"	"	1/4	1	2			"	4		
	06	200	"	0	0				"	4		
	07	"	"	0	0				"	4		
	08	"	"	0	1				"	4		
	09	"	"	0	0		3	136	"	4		
	10	195	"	0	1				"	4		5-10-12
	11	"	F.C.	1/4	1				"	4		
	12	"	"	1/4	1		2		"	0		5-12-20 19280
	13	200	"	0	1				"	0		
	14	"	"	0	1				"	0		
	15	"	"	0	0				"	0		5-15-10
	16	190	B.C.	1/4	2	2		68	"	0		
	17	"	"	1/4	0				"	0		
	18	195	"	1/4	0				"	0		
	19	"	"	1/4	0				"	0		
	20	190	"	1/4	0				"	0		
	21	200	"	1/4	0	3		51	"	0		
	22	"	"	1/4	0				"	0		5-22-10 19301
	23											Round House.
	24											
	25											
	26											
	27											
	28											
	29											
	30											
	31											
	32											
	33											
	34											
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	51											
	52											
	53											
	54											
	55											
	56											
	57											
	58											
	59											
TOTAL												
AVERAGE												SHEET NO. 19.

FIG. 398. TYPICAL RECORD OF FIELD TEST OF LOCOMOTIVE PERFORMANCE ("FORM 16-A")

As indicated by "Form 16-A" (fig. 398), the tests included observations with regard to length of run, running and standing time, speed, tonnage moved, coal burned, number of cars handled, character of smoke produced, and also information as to the conditions of operation of the locomotive. In tests of yard and transfer service, the speed was obtained by timing a counter attached to the cross-head on the locomotive and, in all other tests, the speed was obtained by noting the time of passing stations, streets or other points from which distances could be readily determined. The observations covered 1,076 locomotive-hours of service, during which time the locomotives under observation traveled 5,806 miles.

These tests and observations were made under service conditions and were undertaken for the purpose of acquiring information not obtainable from the reports and of securing accurate data for comparison with the results of the Committee's locomotive tests made at the Altoona, Pa., testing plant of the Pennsylvania Railroad (section 105.24). The tests also permitted comparisons to be made with reference to the work performed by locomotives in different yards, and were useful as a general check against the figures given in the various railroad reports. The results, combined with the facts recorded on Forms 1 to 5, yielded important data which are hereinafter discussed.

202.07 The Card System of Mechanical Tabulation: The Hollerith system of mechanical tabulation employed in the investigation is based upon the use of cards on which the facts are recorded by perforations which, in turn, provide a means by which the cards may be mechanically sorted to yield any desired combination of results. The locations of the perforations indicate the amounts and, in connection with appropriate column headings, the class of facts recorded. Figs. 399 and 400 represent two sample cards, fig. 399 being a card made up from facts originally recorded on "Form 1" and re-tabulated as the first entry on "Form 1-A" (fig. 396).

A brief description of the operation of the system will indicate some of the possibilities of developing the information transferred to the cards. The cards (figs. 399 and 400) are divided by vertical lines into fields or columns of a width and with a heading appropriate to the special facts under tabulation. Each field consists of columns of figures from 0 to 9, and the punching machine upon which the cards are prepared has punches located in corresponding positions so that when the keys are manipulated a round hole is punched covering the numeral corresponding to the key operated.

The card represented by fig. 399 was punched according to an entry on fig. 396, with the addition of the date, yard number and railroad number shown in the heading. The year (1912) is indicated by the punching out of "2" in the first field or column of the card. Reading the perforations in connection with the field headings, by consecutive columns of perforations from left to right, the card is punched to indicate that road No. 30 (according to an arbitrary classification adopted for the purposes of the investigation) was switching freight cars with locomotive No. 4620 in yard No. 207 (designation on the route map) in Zone No. 9 (the numerical designation of Zone B in Indiana) for 0.50 hours beginning at 6:30 P.M. on the first day of the October report period (Tuesday, October 14), that the locomotive burned 0.14 ton of coal, and that the information was obtained from sheet No. 1.

This card covers the first half-hour of the work of this locomotive at this yard. The remaining five hours of its continuous work are covered by the following five lines entered on "Form 1-A" (fig. 396), and one card was punched in a manner similar to that described for each of these lines. Each card, therefore, contains information covering one hour or fraction thereof.

By the process of punching employed, cards may be punched at the rate of approximately 200 per hour per operator. After being punched they may be sorted by a motor driven sorting machine at the rate of 6,000 to 8,000 per hour, and the information presented in any number of columns may be added simultaneously by the Hollerith tabulating machine at the rate of 6,000 cards per hour.

By means of the sorting machine, cards may be arranged in any order desired. For example, if it is desired to segregate the cards showing the work performed in yard 207 during one observation period, all cards for that period are placed in the sorting machine regardless of the order in which they stand. This number (207), consisting

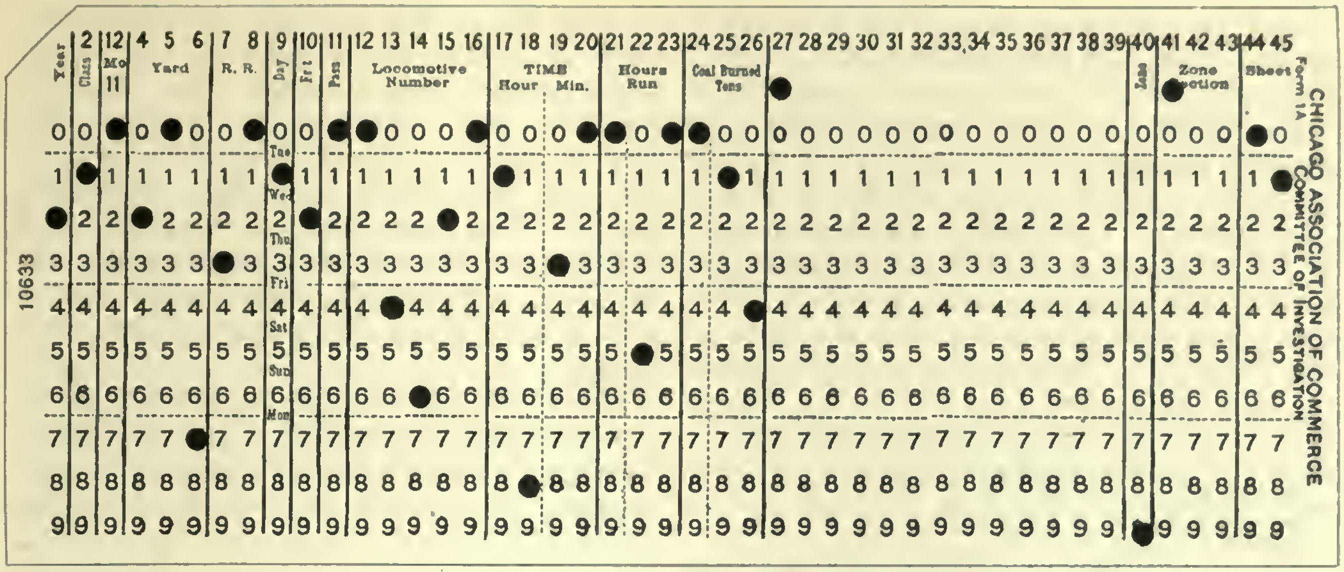

FIG. 399. TYPICAL CARD RECORD OF LOCOMOTIVE MOVEMENT IN YARD SERVICE, FOR USE IN CONNECTION WITH THE HOLLERITH SYSTEM OF AUTOMATIC TABULATION

(Taken from "Form 1-A," fig. 396.)

This card is punched to indicate that Road No. 30 was switching freight cars with Locomotive No. 4620 in Yard No. 207 in Zone No. 9 (Zone B in Indiana) for five-tenths of an hour, beginning at 6:30 P.M. on the first day of the October report period, and that the locomotive burned 0.14 ton of coal; also that the information was obtained from Sheet No. 1.

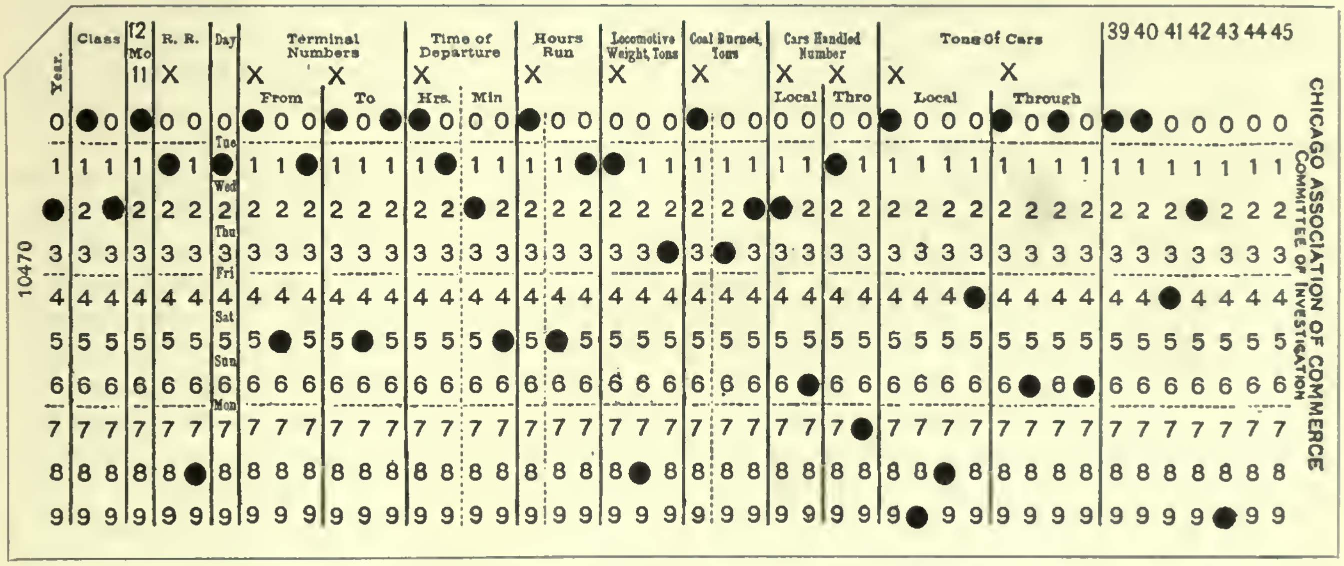

FIG. 400. TYPICAL CARD RECORD OF FREIGHT TRAIN MOVEMENT FOR USE IN CONNECTION WITH THE HOLLERITH SYSTEM OF AUTOMATIC TABULATION

(Taken from "Form 2345-A," fig. 397)

This card is punched to indicate the movement of a Road Freight (Class 2) train operated by Road No. 18 from point No. 51 to point No. 50 on the official route map on the first day of the October report period. The train left point No. 51 at 1:25 A.M. and reached point No. 50, 0.51 hour later. The locomotive weighed 183 tons and burned 0.32 ton of coal during the run. The train consisted of 26 local cars weighing 984 tons, and 17 through cars weighing 605 tons. The information was taken from Sheet No. 4. The distance between points Nos. 51 and 50 is 2.9 miles.

of three figures, requires that the cards be passed through the sorting machine three times, the first time segregating the cards having "2" punched in the first column of the field representing the yard number, the second time those that have "0" punched in the next column and the third time those having "7" punched in the third column.

The tabulation of the cards is accomplished by a motor-driven machine having a series of counters. After being sorted, the cards are placed in the magazine of the tabulator, and as they pass through, one by one, a set of metallic brushes effects an electric contact through the perforations and operates corresponding counters from which the operator may read the totals and record the results.

The information relating to yard switching service, for the five report periods of seven days each, required the use of a total of approximately 319,000 cards.

Fig. 400 represents one of the cards used in connection with "Form 2345-A" (fig. 397) upon which were tabulated the facts concerning road freight, freight transfer, passenger transfer and through and suburban passenger services. In the course of preparing the information, some changes were made which had not been contemplated when the cards were printed. The class column on the card reproduced corresponds to the form on which the original information was received. Both through and suburban passenger services were reported on "Form 5" (fig. 395), and cards for both these subdivisions were punched as class 5. By punching the "4" in the "year" column (which it was unnecessary to use under its original caption) to indicate through service and the "7" in the same column to indicate suburban service, the two passenger services were distinguished from each other. Terminal numbers as recorded represent the element numbers arbitrarily assigned to points on the official route map and serve to define the limits of the movement or of that part of the movement under consideration. Columns 42 and 43 were used to record the length in miles and tenths of a mile of the route element indicated by the terminal numbers. The sheet number is shown in columns 39, 40 and 41. The card, therefore, shows the movement of a road freight train operated by road No. 18 from point No. 51 (Morton Grove) to point No. 50 (city limits) on the official route map on the first day (Tuesday) of the October (tenth month) report period. The train left point No. 51 at 1:25 A.M. and 0.51 hour later reached point No. 50. The locomotive weighed 183 tons and burned 0.32 ton of coal during the run. The train consisted of 26 local cars weighing 984 tons and 17 through cars weighing 606 tons. The distance between points Nos. 51 and 50 is 2.9 miles. The information was taken from sheet No. 4.

In tabulating information for the five report periods under the headings, "Road Freight," "Freight Transfer" and "Passenger Transfer" services, the following numbers of cards were required:

Class 2, Road freight	about 130,000
Class 3, Freight transfer	about 298,000
Class 4, Passenger transfer	about 42,000

In tabulating through and suburban passenger service, it was found that the schedules of several roads had few changes for the different report periods. This permitted the cards punched for the first report period to be used, in some cases, for one or more of the succeeding periods. The actual number of cards punched for the five report periods for passenger service was about 348,000. Had it not been possible to use some of these cards for more than one period, a total of about 644,000 cards would have been required for this service.

The information furnished by the railroads and recorded on the cards, in connection with that shown by test records hereinafter described, was sufficient to permit many facts not recorded in this report to be obtained with comparatively little further work or expense. For example, the total ton-mileage may be subdivided, and the percentage of the total due to the locomotive and to through or local cars obtained. Through car-miles and local car-miles may be shown separately. The number of through and local cars entering the city may also be shown. The traffic within the city limits or within certain subdivisions of the city may be determined for all roads or for each road separately. The proportion of the total traffic which is due to any one road may be obtained for any yard or track section. The hourly flow of traffic in the separate yards may be determined and the track routes which are used by individual roads may be noted. A portion of this information has been developed and is now filed in the Archives of the Committee (Vol. E 46).

From the facts recorded upon the cards prepared from Forms 1 to 5, in combination with those obtained from equipment lists of railroads, it is possible to tabulate the characteristics, such as weight, type and tractive effort of steam locomotives in the several classes of service. The railroads reported the character of the service performed in all yards and, although this was not recorded on cards, it is possible to show the proportions of the locomotive-hours of service, performed at any one yard, devoted to make-up, break-up, classification, industrial switching, switching at freight houses or on team tracks, passenger service or other classes of service.

202.08 Record of Results Obtained from Reports: For the purpose of tabulating the information recorded upon the cards, they were first sorted by "route elements." As defined in section 104.05, a route element is one of the sections into which all the railroad lines in the Area of Investigation were divided for the purpose of aiding in the apportionment of fuel to the districts in which it was consumed. The termini of these elements were fixed as points at which traffic ordinarily might vary in direction or in amount, such as yards or junctions, or at which it crossed the boundaries of either zone of investigation. These elements are shown upon the route map which appears as fig. 11, section 104.05. When the cards had been sorted by route elements, the results of the tabulation were recorded on "Form L," shown as fig. 401 (front) and as fig. 402 (reverse).[*]

The amount of coal burned and the ton-miles of service performed for each hour of the average day were obtained from the records on Forms 1 to 5 by sorting the cards by hours, and diagrams were prepared showing the results.[†]

Tables CLXXII to CLXXVI, inclusive, show the amount of coal consumed, the locomotive mileage and the hours of service for each road and for each class of service for the entire Area of Investigation.

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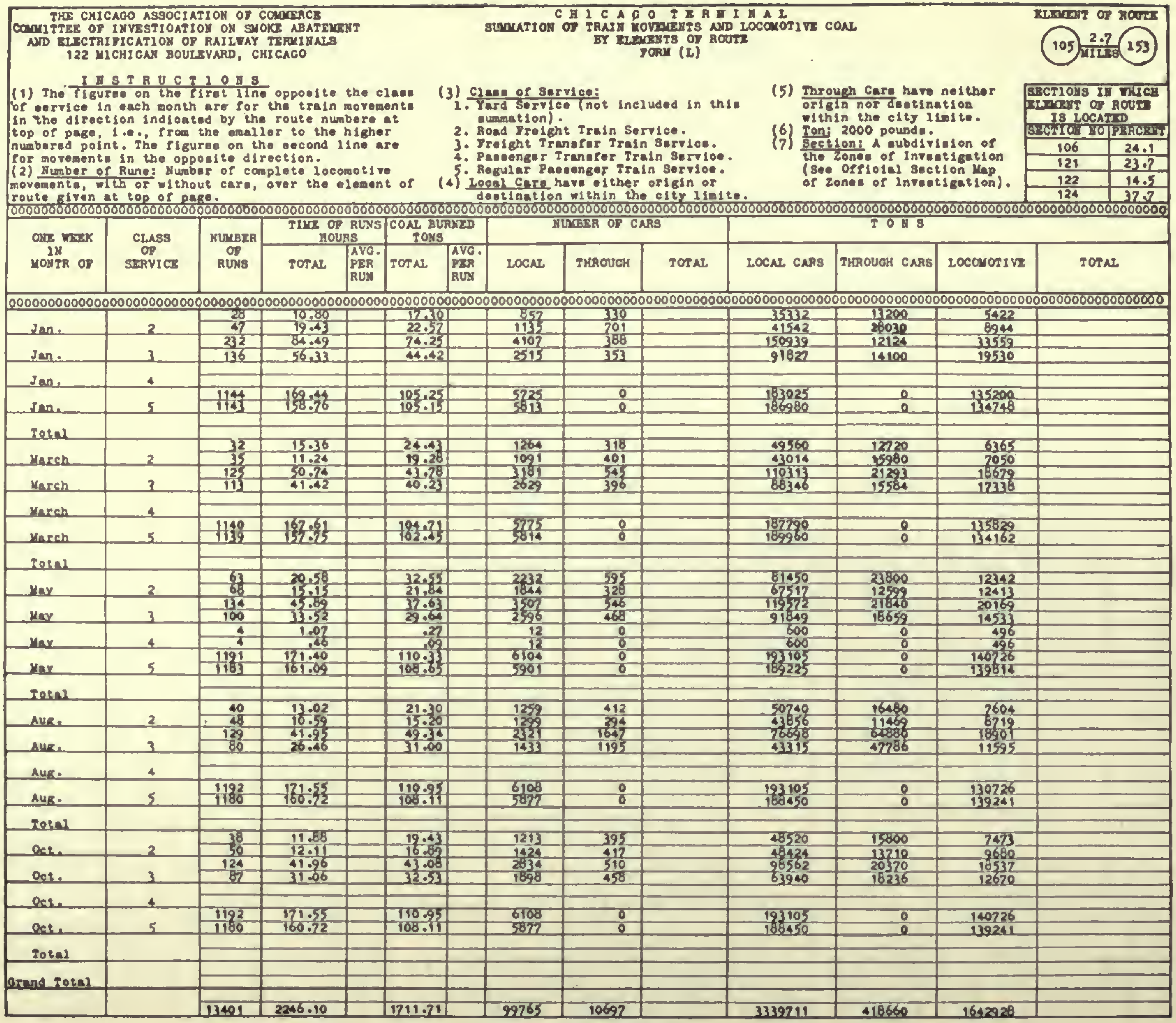
[*] A volume entitled "Summary of Train Movements and Locomotive Coal by Elements of Route," containing "Form L" sheets arranged numerically by elements, on which the data for the various classes of traffic are recorded for each element for each report period, has been made and is preserved in the Archives of the Committee, Vol. E 60. The volume also contains the information on yard switching service tabulated by yards.

[†] The tabulations necessary to obtain the data upon which chapters 104 and 105 of this Report are based, were obtained in the same manner.



THE CHICAGO ASSOCIATION OF COMMERCE
COMMITTEE OF INVESTIGATION ON SMOKE ABATEMENT
AND ELECTRIFICATION OF RAILWAY TERMINALS
122 MICHIGAN BOULEVARD, CHICAGO

CHICAGO TERMINAL
SUMMATION OF TRAIN MOVEMENTS AND LOCOMOTIVE COAL
BY ELEMENTS OF ROUTE
FORM (L)

ELEMENT OF ROUTE
(105) 2.7 MILES (153)

INSTRUCTIONS

(1) The figures on the first line opposite the class of service in each month are for the train movements in the direction indicated by the route numbers at top of page, i.e., from the smaller to the higher numbered point. The figures on the second line are for movements in the opposite direction.
(2) Number of Runs: Number of complete locomotive movements, with or without cars, over the element of route given at top of page.

(3) Class of Service:
1. Yard Service (not included in this summation).
2. Road Freight Train Service.
3. Freight Transfer Train Service.
4. Passenger Transfer Train Service.
5. Regular Passenger Train Service.

(4) Local Cars have either origin or destination within the city limits.

(5) Through Cars have neither origin nor destination within the city limits.
(6) Ton: 2000 pounds.
(7) Section: A subdivision of the Zones of Investigation (See Official Section Map of Zones of Investigation).

SECTIONS IN WHICH ELEMENT OF ROUTE IS LOCATED

SECTION NO	PERCENT
106	24.1
121	23.7
122	14.5
124	37.7

ONE WEEK IN MONTH OF	CLASS OF SERVICE	NUMBER OF RUNS	TIME OF RUNS HOURS		COAL BURNED TONS		NUMBER OF CARS			TONS			
			TOTAL	AVG. PER RUN	TOTAL	AVG. PER RUN	LOCAL	THROUGH	TOTAL	LOCAL CARS	THROUGH CARS	LOCOMOTIVE	TOTAL
Jan.	2	28	10.80		17.30		857	330		35332	13200	5422	
		47	19.43		22.57		1135	701		41542	28030	8944	
Jan.	3	232	84.49		74.25		4107	388		150939	12124	33559	
		136	56.33		44.42		2515	353		91827	14100	19530	
Jan.	4												
Jan.	5	1144	169.44		105.25		5725	0		183025	0	135200	
		1143	158.76		105.15		5813	0		186980	0	134748	
Total													
March	2	32	15.36		24.43		1264	318		49560	12720	6365	
		35	11.24		19.28		1091	401		43014	15980	7050	
March	3	125	50.74		43.78		3181	545		110313	21293	18679	
		113	41.42		40.23		2629	396		88346	15584	17338	
March	4												
March	5	1140	167.61		104.71		5775	0		187790	0	135829	
		1139	157.75		102.45		5814	0		189960	0	134162	
Total													
May	2	63	20.58		32.55		2232	595		81450	23800	12342	
		68	15.15		21.84		1844	328		67517	12599	12413	
May	3	134	45.89		37.63		3507	546		119572	21840	20169	
		100	33.52		29.64		2596	468		91849	18659	14533	
May	4	4	1.07		.27		12	0		600	0	496	
		4	.46		.09		12	0		600	0	496	
May	5	1191	171.40		110.33		6104	0		193105	0	140726	
		1183	161.09		108.65		5901	0		189225	0	139814	
Total													
Aug.	2	40	13.02		21.30		1259	412		50740	16480	7604	
		48	10.59		15.20		1299	294		43856	11469	8719	
Aug.	3	129	41.95		49.34		2321	1647		76698	64886	18901	
		80	26.46		31.00		1433	1195		43315	47786	11595	
Aug.	4												
Aug.	5	1192	171.55		110.95		6108	0		193105	0	130726	
		1180	160.72		108.11		5877	0		188450	0	139241	
Total													
Oct.	2	38	11.88		19.43		1213	395		48520	15800	7473	
		50	12.11		16.89		1424	417		48424	13710	9680	
Oct.	3	124	41.96		43.08		2834	510		96562	20370	18537	
		87	31.06		32.53		1898	458		63940	18236	12670	
Oct.	4												
Oct.	5	1192	171.55		110.95		6108	0		193105	0	140726	
		1180	160.72		108.11		5877	0		188450	0	139241	
Total													
Grand Total		13401	2246.10		1711.71		99765	10697		3339711	418660	1642928	

FIG. 401. "FORM L"

ELEMENT OF ROUTE

(105) 2.7 MILES (153)

CHICAGO TERMINAL

SUMMARY OF TRAIN MOVEMENTS AND LOCOMOTIVE COAL
BY CLASSES OF SERVICE.
INCLUDES MOVEMENTS IN BOTH DIRECTIONS OVER THIS ELEMENT OF ROUTE

CLASS OF SERVICE	NUMBER OF RUNS	TIME OF RUNS HOURS		COAL BURNED TONS		NUMBER OF CARS			TONS			
		TOTAL	AVG. PER RUN	TOTAL	AVG. PER RUN	LOCAL	THROUGH	TOTAL	LOCAL CARS	THROUGH CARS	LOCOMOTIVE	TOTAL
2. ROAD FREIGHT TOTAL FOR 35 DAYS AVERAGE DAY	449.0 12.8	140.16 4.00		210.79 6.02		13618 389	4191 119		509955 14570	163788 4680	86012 2460	
3 FREIGHT TRANSFER TOTAL FOR 35 DAYS AVERAGE DAY	1260.0 36.0	453.82 12.97		425.90 12.18		27021 773	6506 186		935361 26720	254872 7280	185511 5300	
4 PASSENGER TRANSFER TOTAL FOR 35 DAYS AVERAGE DAY	8.0 .2	1.53 .04		.36 .01		24 1	0 0		1200 34	0 0	992 28	
5 REGULAR PASSENGER THROUGH AND SUBURBAN TOTAL FOR 35 DAYS AVERAGE DAY	11684.0 333.9	1650.59 47.30		1074.66 30.65		59102 1690	0 0		1893195 54100	0 0	1370413 39200	
5· REGULAR PASSENGER THROUGH ONLY TOTAL FOR 35 DAYS AVERAGE DAY	1922.0 54.9	214.01 6.11		278.74 7.96		13936 398	0 0		671000 19200	0 0	301334 8610	
5. REGULAR PASSENGER SUBURBAN ONLY TOTAL FOR 35 DAYS AVERAGE DAY	9762.0 279.0	1436.58 41.02		795.92 22.70		45165 1290	0 0		1222195 34900	0 0	1069079 30500	

FIG. 402. REVERSE OF "FORM L"

TABLE CLXXII. RECORD OF LOCOMOTIVE-HOURS OF SERVICE AND OF COAL CONSUMED PER LOCOMOTIVE-HOUR FOR EACH REPORT PERIOD. YARD SERVICE WITHIN AREA OF INVESTIGATION

(Basis of 1912)

Railroad	January 9–15			March 12–18			May 14–20			August 13–19			October 8–14		
	Loco. Hours	Coal Burned Tons	Coal per Loco. Hour Tons	Loco. Hours	Coal Burned Tons	Coal per Loco. Hour Tons	Loco. Hours	Coal Burned Tons	Coal per Loco. Hour Tons	Loco. Hours	Coal Burned Tons	Coal per Loco. Hour Tons	Loco. Hours	Coal Burned Tons	Coal per Loco. Hour Tons
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Atchison, Topeka & Santa Fe Ry	1,231.90	326.08	.26	912.07	273.37	.29	816.46	242.88	.29	840.68	250.99	.29	991.20	297.73	.30
Baltimore & Ohio R. R	735.84	432.58	.58	857.79	519.55	.60	711.57	382.29	.53	686.92	337.10	.48	824.68	374.41	.45
Baltimore & Ohio Chicago Terminal R. R	1,890.13	877.85	.46	1,892.58	782.58	.41	1,823.43	829.70	.45	2,096.15	926.00	.44	2,414.10	1,105.90	.45
Calumet, Hammond & Southeastern R. R	237.00	65.78	.27	210.00	60.90	.28	210.00	60.90	.28	210.00	31.50	.15	210.00	31.50	.15
Chesapeake & Ohio Ry. of Indiana*															
Chicago & Alton R. R	1,558.90	872.59	.56	1,779.28	946.41	.53	1,381.07	644.24	.46	1,072.21	529.04	.49	1,350.15	643.73	.47
Chicago & Calumet River R. R	229.00	20.99	.09	300.00	38.76	.12	156.00	50.07	.31	228.00	26.98	.11	228.00	32.68	.13
Chicago & Eastern Illinois R. R	2,544.93	1,277.43	.50	2,574.53	1,278.62	.50	1,372.61	636.25	.46	2,369.70	1,196.19	.50	2,399.62	1,211.22	.50
Chicago & Erie R. R.†															
Chicago & Illinois Western R. R.*															
Chicago & North Western Ry	7,514.75	4,197.92	.56	7,982.96	4,400.99	.55	8,143.51	3,820.13	.47	8,784.17	4,018.62	.46	11,286.11	5,293.08	.47
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	2,327.49	1,702.60	.73	1,771.85	1,221.48	.69	1,505.16	1,065.07	.71	1,714.17	1,236.16	.72	2,208.49	1,593.27	.72
Chicago, Burlington & Quincy R. R	3,585.41	1,162.15	.32	4,425.46	1,409.17	.32	3,266.49	824.51	.25	3,592.58	1,007.60	.28	3,903.44	1,074.38	.28
Chicago Great Western R. R	591.57	250.66	.42	539.00	212.99	.40	404.26	133.73	.33	543.51	163.08	.30	44.84	191.06	.30
Chicago, Indiana & Southern R. R.*															
Chicago, Indianapolis & Louisville Ry	254.08	114.00	.45	269.50	142.00	.53	257.06	126.50	.49	238.25	124.00	.52	241.15	128.00	.53
Chicago Junction Ry	4,272.42	2,025.63	.47	4,164.59	1,894.34	.45	3,578.52	1,294.38	.36	4,025.49	1,617.43	.40	4,701.85	1,902.60	.40
Chicago, Milwaukee & St. Paul Ry	5,795.68	2,927.17	.51	6,131.59	1,836.79	.30	6,643.68	1,091.28	.16	6,674.96	1,053.47	.16	4,956.89	1,143.63	.23
Chicago River & Indiana R. R.‡															
Chicago, Rock Island & Pacific Ry	3,327.93	1,394.80	.42	3,389.24	1,185.76	.35	3,259.46	1,174.47	.36	3,187.03	1,083.25	.36	3,501.57	1,609.59	.46
Chicago Short Line Ry.†															
Chicago Union Transfer Ry	73.75	32.00	.43	170.66	63.61	.37	160.66	69.50	.43						
Chicago, West Pullman & Southern R. R	756.67	269.21	.36	756.67	268.91	.36	814.82	132.26	.16	804.33	130.68	.16	756.67	269.21	.36
Elgin, Joliet & Eastern Ry	4,354.62	1,457.40	.33	4,876.71	1,605.89	.33	5,096.00	1,310.80	.26	5,169.00	1,625.07	.31	5,232.00	1,732.58	.33
Grand Trunk Western Ry	642.00	282.01	.44	548.69	274.01	.50	473.10	209.25	.44	453.00	226.50	.50	407.00	174.75	.43
Illinois Central R. R	2,558.42	1,455.22	.57	3,180.69	2,040.96	.64	2,426.50	1,422.21	.59	2,135.50	1,247.10	.58	2,223.00	1,261.51	.57
Illinois Northern Ry	280.75	112.49	.40	308.31	126.75	.41	318.48	144.92	.46	334.81	134.12	.40	318.48	144.92	.46
Indiana Harbor Belt R. R	2,873.42	1,126.06	.39	3,996.17	1,934.34	.48	2,713.17	1,327.04	.49	2,952.45	1,446.24	.49	3,879.01	1,815.26	.47
Lake Shore & Michigan Southern Ry	2,726.92	1,098.87	.40	2,653.34	1,080.80	.41	2,147.04	904.39	.42	2,218.87	906.70	.41	2,522.37	1,030.88	.41
Manufacturers' Junction Ry	121.41	23.88	.20	124.34	23.75	.19	114.88	24.01	.21	106.58	20.25	.19	114.82	23.77	.21
Michigan Central R. R	1,460.81	518.50	.35	1,587.75	403.08	.25	1,546.59	388.74	.25	1,373.15	348.68	.25	1,499.95	378.36	.25
Minneapolis, St. Paul & Sault Ste. Marie Ry	479.25	136.10	.28	418.32	137.73	.32	411.91	110.47	.27	356.00	87.70	.25	361.17	94.50	.26
New York, Chicago & St. Louis R. R	977.41	366.73	.38	913.91	400.67	.44	748.06	326.49	.44	693.50	311.20	.45	793.33	349.98	.44
Pere Marquette R. R	283.01	117.15	.41	323.42	134.51	.42	149.41	65.50	.44	401.53	164.63	.41	413.58	196.63	.48
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	1,694.95	776.00	.46	2,781.97	1,107.51	.40	1,608.66	481.49	.30	2,019.36	613.68	.30	2,582.75	929.92	.36
Pittsburgh, Fort Wayne & Chicago Ry	3,698.99	1,643.15	.44	3,779.00	1,575.86	.42	2,986.97	1,016.83	.34	3,302.99	1,281.04	.39	4,057.22	1,622.49	.40
Pullman Railroad	268.75	124.50	.46	268.75	124.50	.46	268.75	124.50	.46	268.75	124.50	.46	268.75	124.50	.46
Wabash Railroad	1,370.42	685.25	.50	1,208.49	597.53	.48	1,103.09	553.87	.50	1,183.57	590.05	.50	1,236.50	606.75	.49
Totals	60,718.58	27,872.75	.46	65,097.63	28,104.12	.43	56,617.97	20,988.67	.37	60,037.21	22,859.55	.38	66,528.69	27,388.79	.41

* No service.

† No report.

‡ Included in the Chicago Junction Ry.

TABLE CLXXIII. RECORD OF LOCOMOTIVE-HOURS OF SERVICE, OF LOCOMOTIVE-MILEAGE AND OF COAL CONSUMED PER LOCOMOTIVE-HOUR FOR EACH REPORT PERIOD. ROAD FREIGHT SERVICE WITHIN AREA OF INVESTIGATION

(Basis of 1912)

Railroad	January 9–15				March 12–18				May 14–20				August 13–19				October 8–14			
	Loco. Hours	Coal Burned Tons	Coal per Loco. Hour Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per Loco. Hour Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per Loco. Hour Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per Loco. Hour Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per Loco. Hour Tons	Loco. Mileage
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Atchison, Topeka & Santa Fe Ry	81.64	82.33	1.00	899.8	63.56	78.18	1.23	968.0	64.62	77.02	1.20	942.0	56.33	64.66	1.14	836.2	74.04	84.65	1.13	1,110 5
Baltimore & Ohio R. R	124.96	177.47	1.42	1,574.0	160.45	231.29	1.44	2,116.5	178.57	168.16	0.94	1,322.5	193.96	147.13	0.76	1,452.8	223.68	198.33	0.88	1,764 0
Baltimore & Ohio Chicago Terminal R. R.*																				
Calumet, Hammond & Southeastern R. R.*																				
Chesapeake & Ohio Ry. of Indiana*																				
Chicago & Alton R. R	62.26	28.38	0.45	882.3	127.16	168.00	1.32	1,280.8	88.18	112.38	1.27	874.3	127.99	126.67	0.99	963.0	99.65	112.26	1.12	861.4
Chicago & Calumet River R. R.*																				
Chicago & Eastern Illinois R. R	95.05	93.62	0.98	707.0	105.54	106.73	1.01	540.0	88.04	87.66	0.99	1,016.9	79.23	80.82	1.02	510.6	92.66	92.11	0.99	499.6
Chicago & Erie R. R. †																				
Chicago & Illinois Western R. R.*																				
Chicago & North Western Ry	786.00	703.68	0.90	5,547.6	707.13	582.21	0.82	5,599.1	554.79	529.79	0.94	5,398.7	717.00	663.84	0.92	6,103.5	713.86	522.12	0.73	4,511.9
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago*																				
Chicago, Burlington & Quincy R. R	253.74	298.60	1.18	2,661.8	267.96	316.64	1.18	2,971.7	187.61	182.12	0.96	2,088.4	219.67	229.47	1.04	2,829.2	283.10	274.62	0.96	3,028 0
Chicago Great Western R. R	35.70	66.40	1.79	458.8	38.19	69.58	1.82	551.8	37.55	63.59	1.69	434.0	35.26	29.35	0.83	461.6	34.53	42.80	1.24	471.2
Chicago, Indiana & Southern R. R	64.88	59.06	0.92	318.9	57.54	52.32	0.91	306 7	17.04	13.28	0.76	232.9	29.17	26.11	0.89	258.6	26.55	26.56	0.99	241 6
Chicago, Indianapolis & Louisville Ry	2.93	7.00	2.39	32.2	7.04	10.51	1.49	85.7	20.37	30.01	1.48	298.4	35.95	64.20	1,79	553.4	22.04	30.97	1.38	254 4
Chicago Junction Ry.*																				
Chicago, Milwaukee & St. Paul Ry	624.80	692.96	1.11	5,896.1	707.74	599.89	0.84	6,903.2	567.55	445.70	0.78	6,071.1	516.54	413.13	0.80	5,448.5	387.52	317.16	0.81	3,693.1
Chicago River & Indiana R. R.*																				
Chicago, Rock Island & Pacific Ry	13.01	18.43	1.41	188.5	18.99	34.22	1.81	296.5	32.36	39.22	1.22	349.6	37.97	41.09	1.08	346.5	43.68	43.60	0.99	350 4
Chicago Short Line Ry.*																				
Chicago Union Transfer Ry.*																				
Chicago, West Pullman & Southern R. R.*																				
Elgin, Joliet & Eastern Ry	172.15	165.92	0.96	1,057.6	172.15	165.92	0.96	1,058.3	173.12	192.14	1.11	1,112.0	172.25	172.95	1.00	1,056.0	184.61	181.87	0.98	1,098.4
Grand Trunk Western Ry	118.21	84.45	0.71	1,651.4	101.40	70.86	0.70	1,521.0	129.15	69.84	0.54	1,812.9	128.57	81.94	0.63	2,080.2	141.08	85.75	0.60	2,261.6
Illinois Central R. R	461.88	753.10	1.64	2,783.2	468.31	766.23	1.64	2,611.7	441.91	690.85	1.58	3,055.5	379.08	601.28	1.64	2,613.6	359.70	587.35	1.61	2,493.5
Illinois Northern Ry.*																				
Indiana Harbor Belt R. R	3.00	1.19	0.39	18.0	7.59	2.15	0.27	24.0	5.33	1.67	0.31	36.0	7.96	7.32	0.91	53.1	6.00	1.71	0.28	36.0
Lake Shore & Michigan Southern Ry	348.10	298.73	0.85	2,822.8	314.12	440.55	1.40	3,485.9	201.34	293.12	1.45	2,532.6	198.76	342.25	1.72	2,594.8	256.77	349.16	1.35	2,942.8
Manufacturers' Junction Ry.*																				
Michigan Central R. R	165.79	117.99	0.71	1,434.2	112.43	94.78	0.85	1,128.2	95.34	118.67	1.24	1,068.6	27.92	30.37	1.08	394.8	34.10	31.52	0.92	408 7
Minneapolis, St. Paul & Sault Ste. Marie Ry.*																				
New York, Chicago & St. Louis R. R	149.54	169.16	1.13	1,691.4	174.15	169.80	0.97	2,290.1	117.39	121.60	1.03	1,483.5	98.70	82.81	0.84	1,499.5	131.23	108.51	0.82	1,623 9
Pere Marquette R. R	60.44	59.20	0.98	382.8	104.66	125.81	1.20	709.1	55.95	66.27	1.18	449.2	35.00	36.25	1.03	246.8	126.90	149.00	1.17	852 9
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	352.55	427.02	1.21	3,695.5	496.10	517.56	1.04	4,532.6	377.28	431.48	1.16	4,018 2	303.61	397.48	1.31	3,949.0	388.84	457.78	1.17	4,590.0
Pittsburgh, Fort Wayne & Chicago Ry	461.32	375.66	0.81	4,271.3	606.46	533.60	0.87	6,016.3	388.50	347.91	0.89	4,324.0	477.19	423.35	0.88	4,773.7	497.35	407.64	0.81	4,822 3
Pullman Railroad*																				
Wabash Railroad	285.63	233.31	0.82	2,052.9	284.34	237.69	0.83	2,210.6	306.14	259.91	0.84	2,404.0	283.47	235.78	1.02	2,044.0	304.58	252 55	0.82	2,374 0
Totals	4.723.58	4,913.66	1.04	41 028.1	5,103.01	5,374.52	1.05	47,207.8	4,128.13	4,342.39	1.05	41,325.3	4,161.58	4,298.25	1.03	4,1069.4	4,432.47	4,358.02	0.98	40,290.2

* No service.

† No report.

TABLE CLXXIV. RECORD OF LOCOMOTIVE-HOURS OF SERVICE, OF LOCOMOTIVE-MILEAGE AND OF COAL CONSUMED PER LOCOMOTIVE-HOUR FOR EACH REPORT PERIOD. FREIGHT TRANSFER SERVICE WITHIN AREA OF INVESTIGATION

(Basis of 1912)

Railroad	January 5–19				March 12–18				May 14–20				August 13–19				October 8–14			
	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Atchison, Topeka & Santa Fe Ry	97.02	54.46	0.56	586.8	162.06	61.03	0.37	939.8	139.43	51.71	0.37	1,001.9	151.20	56.26	0.37	1,008.9	160.90	62.60	0.39	955.4
Baltimore & Ohio R. R	267.03	411.24	1.54	1,641.5	331.85	565.95	1.70	2,000.6	196.14	299.10	1.52	1,501.8	166.78	247.57	1.48	1,502.8	231.36	277.63	1.20	1,632.8
Baltimore & Ohio Chicago Terminal R. R	618.12	392.43	0.64	3,294.4	749.65	508.85	0.67	3,871.5	637.27	476.54	0.74	3,317.0	765.56	497.09	0.64	4,323.9	1,131.86	746.46	0.65	5,256.8
Calumet, Hammond & Southeastern R. R.*																				
Chesapeake & Ohio Ry. of Indiana	35.44	48.98	1.38	292.6	35.44	49.00	1.38	294.4	35.44	49.00	1.38	294.4	35.44	49.00	1.38	294.4	35.44	49.00	1.38	294.4
Chicago & Alton R. R	216.48	72.75	0.33	939.4	394.52	337.93	0.85	1,701.2	140.14	80.74	0.57	884.6	229.04	132.72	0.58	1,388.4	262.73	161.14	0.61	1.459.3
Chicago & Calumet River R. R.*																				
Chicago & Eastern Illinois R. R	470.03	462.79	0.98	1,667.1	488.19	490.52	1.00	2,017.4	326.16	322.55	0.99	1,385.2	388.58	393.03	1.01	1,609.7	353.07	355.26	1.00	1,490.9
Chicago & Erie R. R.†																				
Chicago & Illinois Western R. R	8.75	22.44	2.56	81.6	8 75	22.44	2.56	81.6	8.75	22.44	2.55	81.6	8.75	22.44	2.55	81.6	8.75	22.44	2.55	81.6
Chicago & North Western Ry	1,067.35	2,024.06	1.90	5,414.5	982.78	1,449.73	1.47	5,616 9	856.02	1,321.40	1.54	5,544.4	978.76	1,498.73	1.54	6,067.5	1,126.81	1,705.59	1.52	7,713.1
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	1,425.93	1,004.33	0.70	8,125.7	1,352.20	939.28	0.69	7,770.6	1,115.82	922.25	0.82	6,810.5	1,369.88	1,116.37	0.81	9,147.8	1,599.05	1,313.33	0.82	9,897.7
Chicago, Burlington & Quincy R. R.	902.56	331.99	0.36	5,267.6	1,018.85	356.67	0.35	5,518.9	680.08	193.15	0.28	4,212.8	706.61	215.24	0.30	4,527.8	827.63	234.81	0.28	4,691.9
Chicago Great Western R. R	49 88	27.99	0.56	287.4	59.20	29.95	0.50	355.8	42 29	21.34	0.50	305.4	35.99	22.75	0.63	288.0	39.83	37.25	0.93	270.0
Chicago, Indiana & Southern R. R.*																				
Chicago, Indianapolis & Louisville Ry	147.96	213.65	1.44	1,161.4	166 29	197.92	1.19	1,179.0	149.29	184.45	1.23	1,176.1	130.23	185.68	1.40	1,098.5	134.20	200.49	1.52	1,117.5
Chicago Junction Ry.*																				
Chicago, Milwaukee & St. Paul Ry	895.89	422 98	0.47	3,574.9	1,270.54	563.72	0.44	5,228.5	915.18	262.49	0.28	4,134.7	1,248 78	316.21	0.25	4,727.6	1,510.51	424.88	0.27	5,260.2
Chicago River & Indiana R. R.*																				
Chicago, Rock Island & Pacific Ry	631.90	261.49	0.41	3,343.8	650.34	219.93	0.33	3,199.8	682.42	231.88	0.34	3,710.5	600.61	204.69	0.33	3,566.9	758.70	345.03	0.45	3,829.2
Chicago Short Line Ry.*																				
Chicago Union Transfer Ry.*																				
Chicago, West Pullman & Southern R. R	35.82	10.59	0.29	121.2	20.91	8.12	0.38	87.2	37.22	11.41	0.30	140.7	35.82	10.59	0.29	121.2	35.82	10.59	0.29	121.2
Elgin, Joliet & Eastern Ry	273.89	367.65	1.31	2,183.9	273.77	367.60	1.34	2,176.4	339.68	400.66	1.21	2,138.3	273.23	366.81	1.34	2,197.6	226.07	386.06	1.71	2,115.0
Grand Trunk Western Ry	98.51	89.23	0.90	248.9	78.00	70.36	0.90	505.5	81.49	47.44	0.58	510.0	68.35	40.00	0.58	417.8	79.19	45.77	0.57	489.0
Illinois Central R. R	934.53	864.73	0.92	5,579.7	375.21	401.33	1.06	2,193.9	335.82	329.45	0.98	2,219.4	349.73	488.20	1.37	2,152.9	412.28	496.72	1.20	2,424.9
Illinois Northern Ry	96.48	89.28	0.92	248.9	96.00	98.28	1.02	205.2	111.89	110.86	0.99	290.7	112.56	91.00	0.80	256 2	96.48	98.58	1.02	206.4
Indiana Harbor Belt R. R	1,359.60	1,161.93	0.86	8,572.2	1,636.77	1,272.98	0.77	10,451.0	1,096.59	801.49	0.73	8,042.0	1,143.92	857.88	0.75	8 592.6	1,452.55	1,097.35	0.75	10,338.6
Lake Shore & Michigan Southern Ry.	551.09	227.10	0.40	3,258.7	417 34	176.12	0.41	2,552.1	330.30	137.31	0.41	2,482.3	316.46	133.20	0.42	2,328.7	467.40	193.31	0.41	2,789.0
Manufacturers' Junction Ry	14.12	3.23	0.22	126.8	20 29	4.10	0.20	138.8	20.08	4.22	0.21	136.4	23.82	5.50	0.23	138.8	32.51	6.24	0.91	136.2
Michigan Central R. R	436.36	193.61	0.44	3,004 3	405.07	133.57	0.33	2,796.1	330.78	164.63	0.48	3,243.0	277.75	148.30	0.53	2,516.5	298.70	164.84	0.55	2,731.2
Minneapolis, St. Paul & Sault Ste. Marie Ry	434.91	162.60	0.37	1,685.2	284.72	148.47	0.52	1,515.8	225 07	116.77	0.51	1,516.8	196.93	90.98	0.46	1,210.8	271.34	112.08	0.41	1,691.2
New York, Chicago & St. Louis R. R.	632.57	293.61	0.46	1,574 2	525.18	347.44	0.67	1,778.6	417.52	267.29	0.65	1,513.0	435.13	281.21	0.65	1,555.8	460.97	292.94	0.63	1,543.1
Pere Marquette R. R	149.92	86.43	0.57	629.0	103.68	64.54	0.62	433.0	121.93	85.45	0.70	621.0	102.30	123.50	1.20	630.9	110.10	144.89	1.31	768.6
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	523.55	195.20	0.37	3,232 8	672.22	232.52	0.34	4,814.7	503.36	135.85	0.27	3,551.3	530.43	121.40	0.22	3,706.1	548.39	153.96	0.28	3,694 5
Pittsburgh, Fort Wayne & Chicago Ry	566.93	211.38	0.37	2,512.9	634.49	225.58	0.35	2,629.9	558.18	168.43	0.30	2,504.8	508.38	147.18	0.28	2,265.4	560.39	174.12	0.31	2,568.0
Pullman Railroad*																				
Wabash Railroad	211.44	124 79	0.59	1,146.4	280.29	149.13	0.53	1,678.6	255.13	143.59	0.56	1,436.7	244.41	138.46	0.56	1,354.8	221.09	123.90	0.56	1,382.4
Totals	13,154.06	9,832.94	0.74	69,803.8	13,494.60	9,493.06	0.70	73,732.8	10,689.47	7,363.89	0.69	64,797.3	11,435.43	8,002.02	0.70	69,179.9	13,454.12	9,437.26	0.70	76,950.1

* No report.

† No service.

TABLE CLXXV. RECORD OF LOCOMOTIVE-HOURS OF SERVICE, OF LOCOMOTIVE-MILEAGE AND OF COAL CONSUMED PER LOCOMOTIVE-HOUR FOR EACH REPORT PERIOD. PASSENGER TRANSFER SERVICE WITHIN AREA OF INVESTIGATION

(Basis of 1912)

Railroad	January 9–15				March 12–18				May 14–20				August 13–19				October 8–14			
	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Atchison, Topeka & Santa Fe Ry	7.16	3.11	.43	25.8	30.99	23.05	.74	211.2	31.30	22.47	.71	336.6	22.82	17.58	.75	186.2	24.69	18.33	.74	191.5
Baltimore & Ohio R. R.*																				
Baltimore & Ohio Chicago Terminal R. R.*																				
Calumet, Hammond & Southeastern R. R.†																				
Chesapeake & Ohio Ry. of Indiana.†																				
Chicago & Alton R. R.	21.65	5.16	.23	112.8	2.42	.88	.36	11.2	2.09	1.45	.69	12.2	12.25	5.96	.49	95.1	41.34	21.83	.52	254.2
Chicago & Calumet River R. R.†																				
Chicago & Eastern Illinois R. R.†																				
Chicago & Erie R. R.†																				
Chicago & Illinois Western R. R.†																				
Chicago & North Western Ry	165.30	56.21	.33	1,042.5	233.22	121.39	.51	1,869.9	167.23	56.44	.33	1,054.9	159.62	66.75	.41	1,050.6	184.89	84.33	.45	1,208.1
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	142.13	99.31	.69	1,778.0	53.26	37.88	.71	1,525.3	52.73	37.05	.70	1,527.2	92.42	64.93	.70	1,550.2	89.93	63.90	.71	1,560.2
Chicago, Burlington & Quincy R. R.	120.01	39.35	.32	490.2	119.80	31.63	.26	584.1	106.50	24.37	.22	601.2	110.05	26.65	.24	618.1	103.61	27.43	.26	602.9
Chicago Great Western R. R.†																				
Chicago, Indiana & Southern R. R.†																				
Chicago, Indianapolis & Louisville Ry	.94	1.92	.20	19.7	.99	2.01	.20	23.2	.99	2.01	.20	23.2	.99	2.01	.20	23.2	.99	2.01	.20	23.2
Chicago Junction Ry.†																				
Chicago, Milwaukee & St. Paul Ry	164.09	49.85	.30	1080.4	175.41	49.12	.28	1,232.1	141.31	37.92	.26	1,051.2	144.50	38.12	.26	1,082.4	141.28	37.96	.26	1,037.7
Chicago River & Indiana R. R.†																				
Chicago, Rock Island & Pacific Ry	28.89	13.03	.45	251.5	36.53	14.70	.40	320.9	39.94	15.01	.38	351.9	40.58	16.65	.41	396.9	39.81	20.92	.52	331.9
Chicago Short Line Ry.†																				
Chicago Union Transfer Ry.†																				
Chicago, West Pullman & Southern R. R.†																				
Elgin, Joliet & Eastern Ry.†																				
Grand Trunk Western Ry	8.27	8.50	1.03	56.5	8.27	8.50	1.03	56.5	13.66	6.99	.50	83.6	8.27	8.50	1.03	56.5	14.58	8.75	.60	114.6
Illinois Central R. R.	4.37	1.88	.43	22.8	15.36	7.29	.47	45.9	14.59	8.48	.53	64.5	6.83	4.40	.64	27.3	8.88	4.70	.52	21.9
Illinois Northern Ry.†																				
Indiana Harbor Belt R. R.†																				
Lake Shore & Michigan Southern Ry	112.42	50.84	.45	877.4	111.09	46.56	.42	1,176.4	98.55	40.20	.40	1,179.4	94.17	38.88	.41	1,272.1	106.43	43.52	.40	1,323.2
Manufacturers' Junction Ry.†																				
Michigan Central R. R.	53.90	19.20	.35	191.1	44.49	11.48	.25	155.2	38.60	9.95	.25	241.6	21.40	5.55	.25	114.4	18.99	5.11	.26	97.2
Minneapolis, St. Paul & Sault Ste. Marie Ry.*																				
New York, Chicago & St. Louis R. R.	86.87	46.20	.53	467.0	86.87	45.50	.52	474.6	86.87	45.50	.52	474.6	86.87	45.50	.52	474.6	86.87	45.50	.52	474.6
Pere Marquette R. R.†																				
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	6.92	4.03	.57	20.2			Included in P. Ft. W. & C. Ry.													
Pittsburgh Fort Wayne & Chicago Ry	92.23	44.69	.53	306.2	110.23	51.62	.45	558.9	101.55	40.95	.39	431.7	118.13	52.39	.44	407.3	117.46	53.01	.45	340.1
Pullman Railroad†																				
Wabash Railroad†																				
Totals	1,017.24	443.28	.43	6,742.1	1,028.93	451.61	.43	8,245.4	895.91	348.79	.38	7,433.8	918.90	393.87	.42	7,354.9	979.75	437.30	.44	7,581.3

* No report.

† No service.

TABLE CLXXVI. RECORD OF LOCOMOTIVE-HOURS OF SERVICE, OF LOCOMOTIVE-MILEAGE AND OF COAL CONSUMED PER LOCOMOTIVE-HOUR FOR EACH REPORT PERIOD. PASSENGER SERVICE WITHIN AREA OF INVESTIGATION.

(Basis of 1912)

Railroad	January 9–15				March 12–18				May 14–20				August 13–19				October 8–14			
	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage	Loco. Hours	Coal Burned Tons	Coal per L. Hr. Tons	Loco. Mileage
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Atchison, Topeka & Santa Fe Ry	63.22	82.86	1.31	1,590.0	66.43	89.37	1.34	1,595.8	63.08	82.08	1.30	1,555.1	66.40	75.19	1.13	1,536.7	71.37	94.39	1.34	1,737.8
Baltimore & Ohio R. R.	159.32	145.00	.90	2,687.0	153.44	142.23	.92	2,589.7	154 67	143.47	.92	2,620.8	151.66	140.68	.92	2,558.6	157.62	145.08	.92	2,683.0
Baltimore & Ohio Chicago Terminal R. R.	53.05	38.42	.72	1,163.6	53.05	38.42	.72	1,163.6	53.05	38.42	.72	1,163.6	53.05	38.42	.72	1,163.6	53.05	38.42	.72	1,163.6
Calumet, Hammond & Southeastern R. R.*																				
Chesapeake & Ohio Ry. of Indiana	38.04	45.12	1.18	943.3	38.04	45.12	1.18	943.3	38.04	45.12	1.18	943.3	38.04	45.12	1.18	943.3	38.04	45.12	1.18	943.3
Chicago & Alton R. R.	176.32	70.26	.39	2,054.4	172.21	134.93	.78	1,731.1	169.13	132.31	.78	1,794.7	186.92	153.05	.81	2,308.4	180.64	147.12	.81	2,329.0
Chicago & Calumet River R. R.*																				
Chicago & Eastern Illinois R. R.	218.08	299.32	1.37	4,357.2	218.08	299.32	1.37	4,357.2	218.08	299.32	1.37	4,357.2	218.08	299.32	1.37	4,357.2	218.08	299.32	1.37	4,357.2
Chicago & Erie R. R.	109.03	69.52	.64	2,140.4	109.03	69.52	.64	2,140.4	109.03	69.52	.64	2,140.4	109 03	69.52	.64	2,140.4	109.03	69.52	.64	2,140.4
Chicago & Illinois Western R. R.*																				
Chicago & North Western Ry	2,186.84	1,661.17	.73	34,468.7	2,186.21	1,660.22	.73	34,455.4	1,929.96	1,432.06	.74	31,027.7	1,831.42	1,226.12	.65	31,946.6	1,885.08	1,398.96	.74	32,380.5
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	219.05	332.29	1.50	3,986.7	225.90	337.15	1.46	4,173.4	225.90	337.15	1.46	4,173.4	184.58	128.15	.69	3.549.4	169.19	120.00	.70	3,148.2
Chicago, Burlington & Quincy R. R.	465.75	694.59	1.50	10,137.8	465.75	694.59	1.50	10,137.8	465.75	694.59	1.50	10,137.8	408.47	455.82	1.12	9,395.3	408.47	455.82	1.12	9,395.3
Chicago Great Western R. R.	35.37	58.90	1.66	796.5	33.95	55.90	1.64	756.0	33.95	55.90	1.64	756.0	36.77	57.26	1.51	801.1	34.01	56.29	1.65	760.5
Chicago, Indiana & Southern R. R.	66.15	52.50	.79	1,311.6	65.21	57.41	.87	1,459.3	58.36	52.55	.90	1,272.6	60.08	54.47	.90	1,300.2	60.00	56.30	.93	1,271.2
Chicago, Indianapolis & Louisville Ry	104.56	299.18	2.86	2,254.6	118.43	334.18	2.79	2,579.4	99.78	211.09	2.11	2,273.7	94.65	219.13	2.31	2,274.0	92.24	262.25	2.83	2,352.7
Chicago Junction Ry.*																				
Chicago, Milwaukee & St. Paul Ry	534.40	649.28	1.21	11,256.1	545.06	650.68	1.19	11,447.5	531.91	638.51	1.20	11,157.6	521.66	627.77	1.20	11,114.9	522.86	626.42	1.20	11,152.4
Chicago River & Indiana R. R.*																				
Chicago, Rock Island & Pacific Ry	632.74	770.61	1.22	13,253.9	611.27	753 67	1.23	13,005.5	609.70	753.58	1.23	12,984.4	582.80	731.12	1.25	12,535.4	588.76	734.94	1.25	12,711.3
Chicago Short Line Ry.*																				
Chicago Union Transfer Ry.*																				
Chicago, West Pullman & Southern R. R.*																				
Elgin, Joliet & Eastern Ry.*																				
Grand Trunk Western Ry	193.29	343.05	1.80	4,157.2	186.62	331.05	1.78	4,024.2	196.37	211.05	1.08	4,355.3	191 17	209.30	1.09	4,109.4	204.39	217.08	1.06	4,536.8
Illinois Central R. R.	1,733.64	1,052.95	.60	31,836.0	1,733.64	1,052.95	.60	31,836.0	1514.92	1,100.15	.60	33,940.8	1,814.92	1,100.15	.60	33,940.8	1,814.92	1,100.15	.60	33,940.8
Illinois Northern Ry.*																				
Indiana Harbor Belt R. R.*																				
Lake Shore & Michigan Southern Ry	707.26	655.11	.92	15,683.4	646.12	585.75	.90	14,520.9	638.84	576.85	.90	14,159.0	630.10	569.41	.90	14,214.8	629.65	569.46	.90	14,196.2
Manufacturers' Junction Ry.*																				
Michigan Central R. R.	198.71	259.96	1.30	4,223.9	174.05	220.55	1.29	4,078.0	167.20	273.44	1.63	4,113.1	161.95	265.75	1.64	3,992.6	161.95	265.75	1.64	3.992.6
Minneapolis, St. Paul & Sault Ste. Marie Ry	125.76	111.97	.88	1,662.0	125.76	111.97	.88	1,662.0	125.76	111.97	.88	1,662.0	143.66	122.19	.85	292.5	125.76	111.97	.88	1,662.0
New York, Chicago & St. Louis R. R.	49.47	64 04	1.29	1,013.0	49.47	64.04	1.29	1,013.0	49.47	64.04	1.29	1,013.0	49.47	64.04	1.29	1,013.0	49.47	64.04	1.29	1,013.0
Pere Marquette R. R.	55.93	87.50	1.56	1,257.6	55.93	87.50	1.56	1,257.6	60.25	74.66	1.23	1,559.1	67.53	104.74	1.55	1,645.7	71.62	92.70	1.29	1,587.5
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	74.02	88.02	1.18	1,207.0	72.51	86.28	1.18	1,179.2	72.51	86.28	1.18	1,179.2	64.88	59.90	.92	1,168.1	57.29	59.22	1.03	1,166.2
Pittsburgh, Fort Wayne & Chicago Ry	689.90	614.08	.90	11,509.5	547.11	528.82	.95	11,035.9	519.79	506.80	.97	10,546.8	584.57	479.43	.81	10,756.3	580.18	508.80	.87	10,964.8
Pullman Railroad*																				
Wabash Railroad	383.65	220.33	.57	4,623.0	312.73	195.08	.62	4,239.7	335.64	206.10	.61	4,475.4	338.85	212.23	.62	4.409.4	335.86	211.25	.62	4,537.2
Totals	9,273.64	8,766.03	.94	169,575.3	8,966.00	8,626.70	.96	167,381.9	8,741.14	8,197.01	.92	165.302.0	8,590.71	7,508 28	.87	163,467.7	8,619.53	7,750.37	.89	166,123.5

* No service.

Table CLXXII shows the number of locomotive-hours, number of tons of coal consumed and the amount of coal consumed per locomotive-hour in yard service, as reported by 32 railroads for each of the five observation periods of seven 24-hour days.

Table CLXXIII shows the number of locomotive-hours, the number of tons of coal consumed, the amount of coal consumed per locomotive-hour and the locomotive-mileage in road freight service, on 22 railroads for each of the five observation periods of seven 24-hour days.

Table CLXXIV presents information of the same character as that contained in table CLXXIII, for freight transfer service on 29 railroads for each of the observation periods.

Table CLXXV presents information of the same character as that contained in table CLXXIII, for passenger transfer service on 15 railroads for each of the observation periods.

Table CLXXVI presents information of the same character as that included in table CLXXIII for passenger service on 25 railroads for each of the observation periods.

It was not deemed necessary to compile the reports for all the periods on an hourly basis because the variation between them was not sufficient to require it. Since, also, omissions in the reports of the earlier periods were made good in the later ones, it was decided to use the October reports as a basis for all hourly segregations. Diagrams from the October reports showing, by hours, the locomotive-mileage, ton-miles, coal consumed and locomotive-hours of service in each class of service, are presented as figs. 403 to 430, inclusive.

Figs. 403 to 409, inclusive, are diagrams showing hourly locomotive mileage for the average October day in yard service (fig. 403); road freight service (fig. 404); freight transfer service (fig. 405); passenger transfer service (fig. 406); through passenger service (fig. 407); suburban passenger service (fig. 408); total freight and passenger service (fig. 409).

Figs. 410 to 416, inclusive, are diagrams showing hourly ton-miles in yard service (fig. 410); road freight service (fig. 411); freight transfer service (fig. 412); passenger transfer service (fig. 413); through passenger service (fig. 414); suburban passenger service (fig. 415); all classes of steam service (fig. 416).

Figs. 417 to 423, inclusive, are diagrams showing coal consumed hourly in yard service (fig. 417); road freight service (fig. 418); freight transfer service (fig. 419); passenger transfer service (fig. 420); through passenger service (fig. 421); suburban passenger service (fig. 422); all classes of steam service (fig. 423).

Figs. 424 to 430, inclusive, are diagrams showing locomotive-hours of service in yard service (fig. 424); road freight service (fig. 425); freight transfer service (fig. 426); passenger transfer service (fig. 427); through passenger service (fig. 428); suburban passenger service (fig. 429); all classes of service (fig. 430).

202.09 Records of Field Tests and Observations: Results of field tests and observations described in section 202.06 are recorded in tables CLXXVII to CLXXXI, inclusive.

Table CLXXVII is a summary of yard locomotive tests, and represents the results obtained from 103 tests on 13 different railroads, ranging from 2 to 29 tests on each road and covering a total of 807.42 hours. The maximum ratio of time in motion to time in service was 77.07 per cent and the minimum was 50.33 per cent; the average was 60.12 per cent. The greatest average speed while in motion during the tests, for any road, was 6.7 miles per hour and the lowest average was 3.6 miles per hour. Loads varied from an average of 191 tons behind the tender, with a maximum for the same road of 1,400 tons, to a maximum average of 425 tons and a maximum load of 3,250 tons. The longest average run was 3,165 feet and the shortest, 393 feet.

A summary of road freight tests, as shown by table CLXXVIII, is tabulated in a similar manner. The record covers the results of 22 tests on 7 railroads. Trains subject to test were in motion an average of 78.4 per cent, ranging from 48.7 to 100 per cent of the observation period, the 100 per cent record, however, covering a single test of 0.32 hour's duration.

Table CLXXXI is made up in a similar manner as a summary of freight and passenger transfer trains, and covers 58 periods of observation on 12 railroads. Passenger trains are included in the records of only two roads. The trailing loads in this summary range from an average of 568 tons, with a maximum of 2,900 tons, to an average of 2,260 tons, with a maximum of 2,290 tons. The average length of run

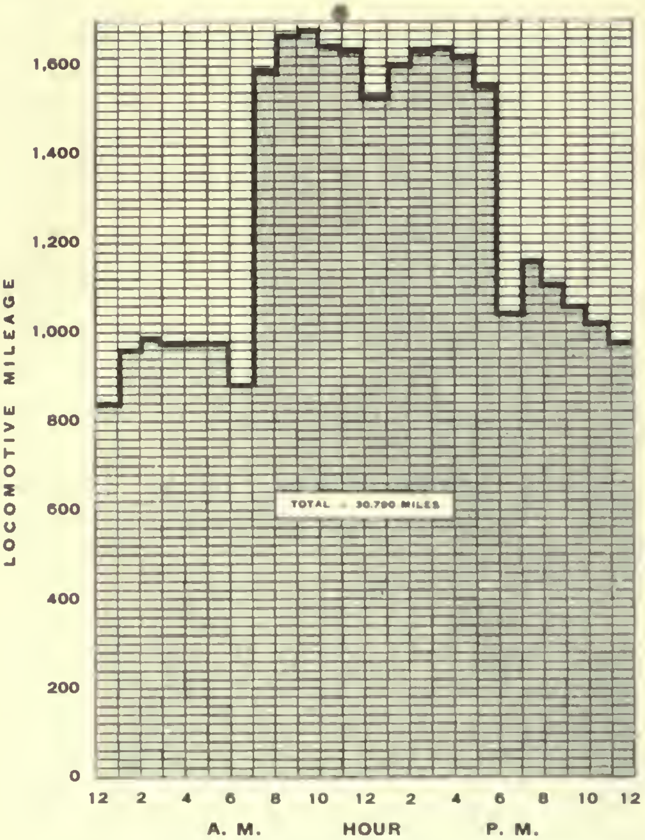


FIG. 403. TRAFFIC DIAGRAM. Locomotive-Mileage for the Average Day for Steam Operation in Yard Switching Service within Area of Investigation.

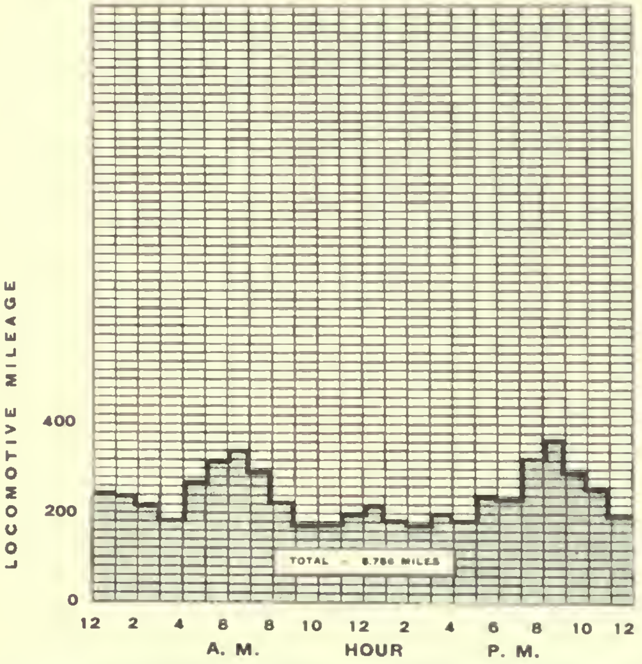


FIG. 404. TRAFFIC DIAGRAM. Locomotive-Mileage for the Average Day for Steam Operation in Road Freight Service within Area of Investigation.

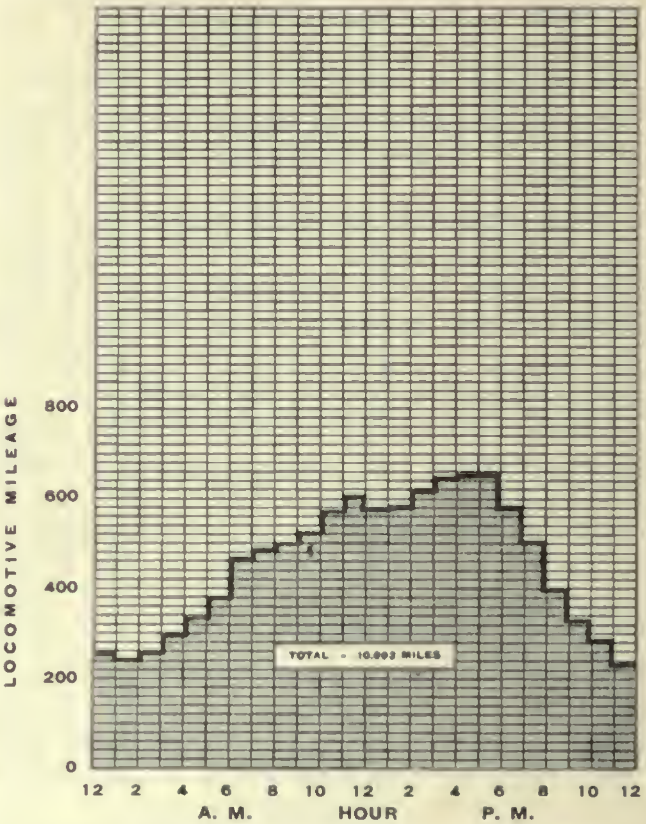


FIG. 405. TRAFFIC DIAGRAM. Locomotive-Mileage for the Average Day for Steam Operation in Freight Transfer Service within Area of Investigation.

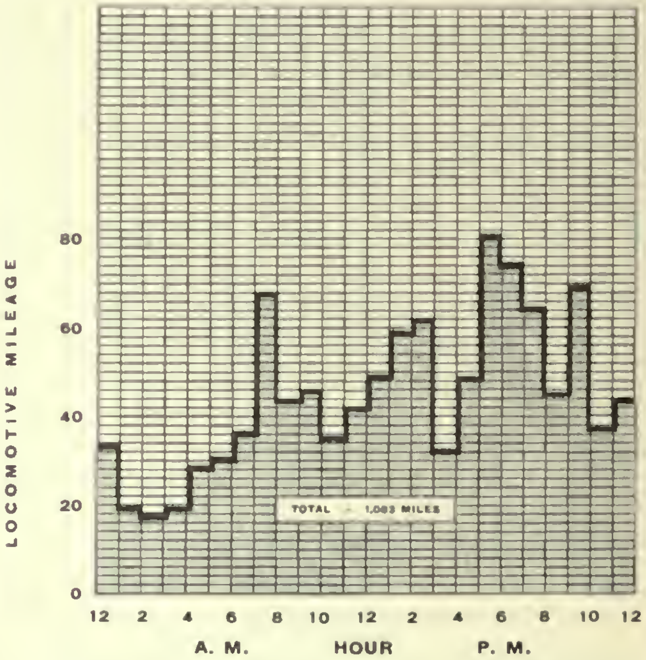


FIG. 406. TRAFFIC DIAGRAM. Locomotive-Mileage for the Average Day for Steam Operation in Passenger Transfer Service within Area of Investigation.

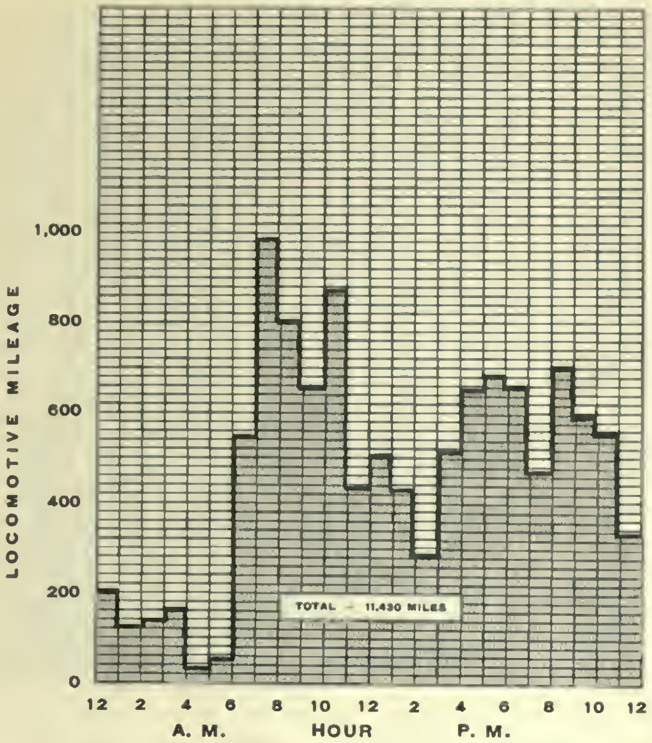


FIG. 407. TRAFFIC DIAGRAM. Locomotive-Mileage for the Average Day for Steam Operation in Through Passenger Service within Area of Investigation.

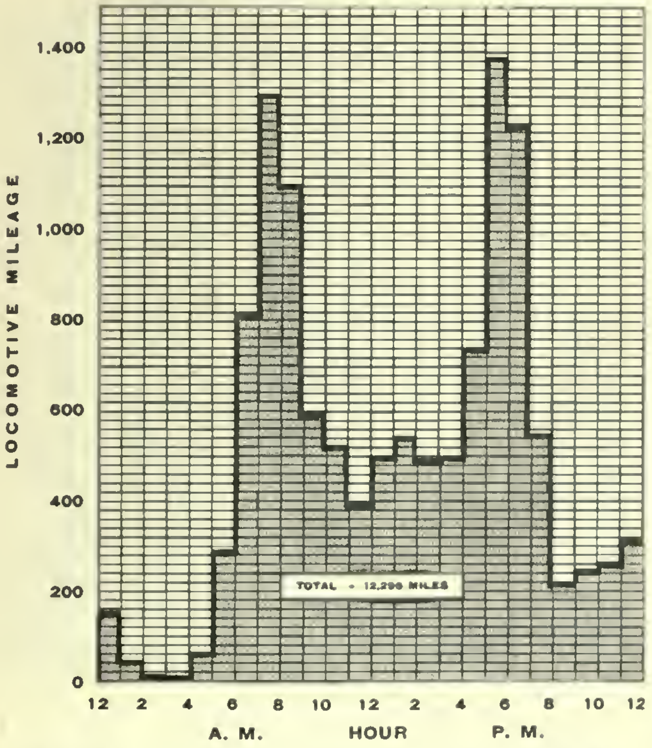


FIG. 408. TRAFFIC DIAGRAM. Locomotive-Mileage for the Average Day for Steam Operation in Suburban Passenger Service within Area of Investigation.

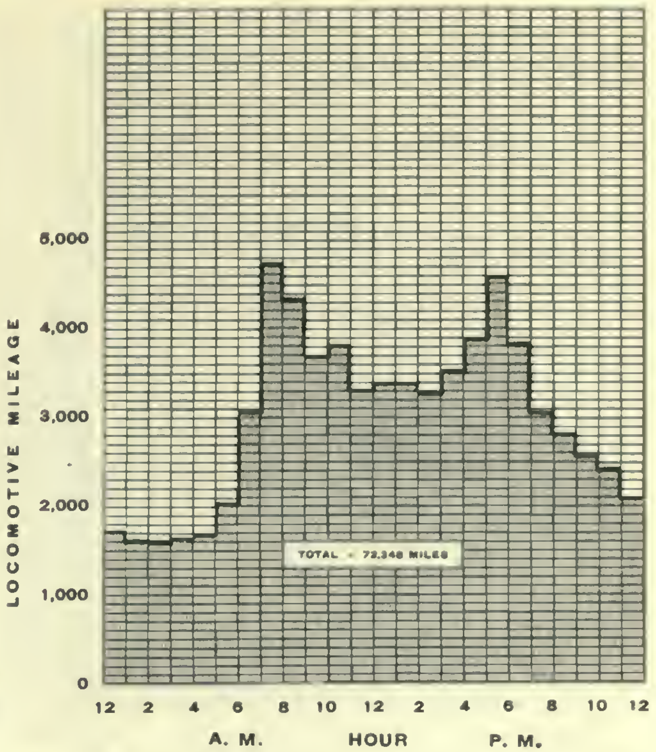


FIG. 409. TRAFFIC DIAGRAM. Total Locomotive-Mileage for the Average Day for Steam Operation in All Classes of Service within Area of Investigation.

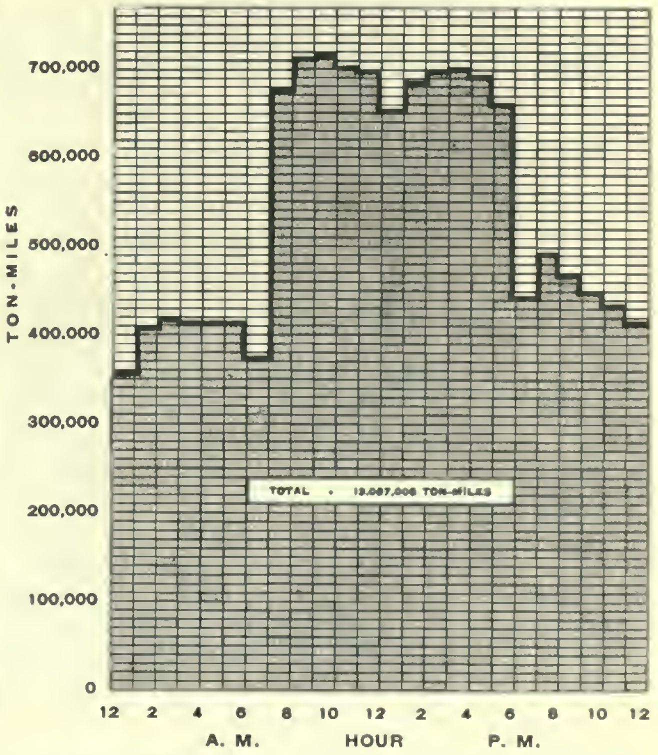


FIG. 410. TRAFFIC DIAGRAM. Ton-Miles for the Average Day for Steam Operation in Yard Switching Service within Area of Investigation.

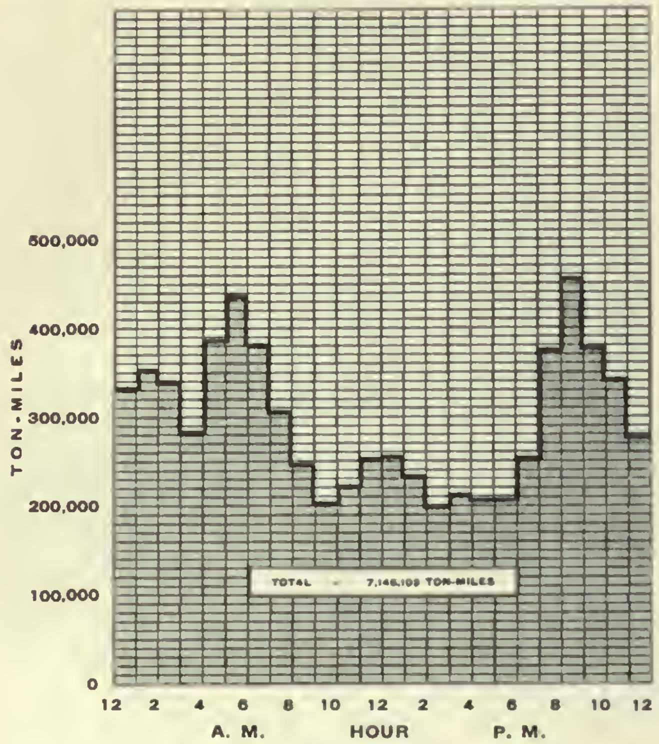


FIG. 411. TRAFFIC DIAGRAM. Ton-Miles for the Average Day for Steam Operation in Road Freight Service within Area of Investigation.

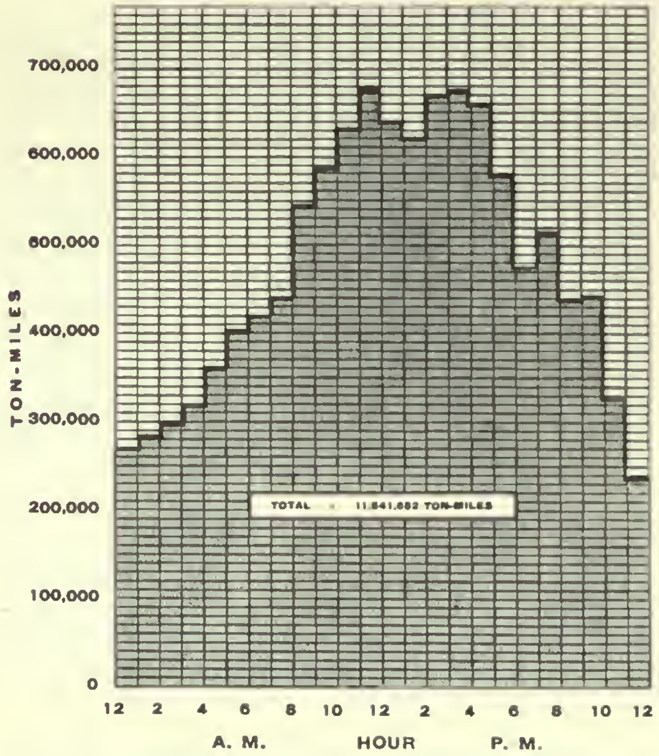


FIG. 412. TRAFFIC DIAGRAM. Ton-Miles for the Average Day for Steam Operation in Freight Transfer Service within Area of Investigation.

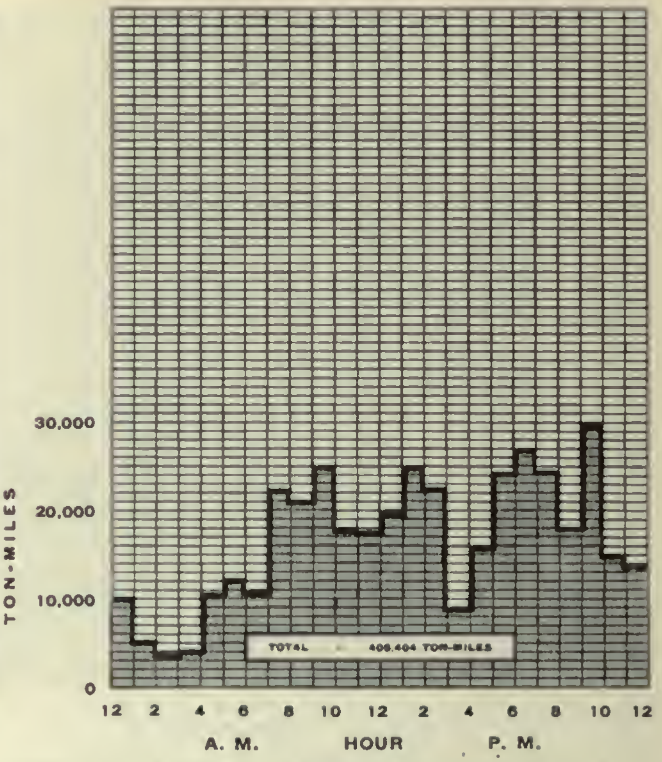


FIG. 413. TRAFFIC DIAGRAM. Ton-Miles for the Average Day for Steam Operation in Passenger Transfer Service within Area of Investigation.

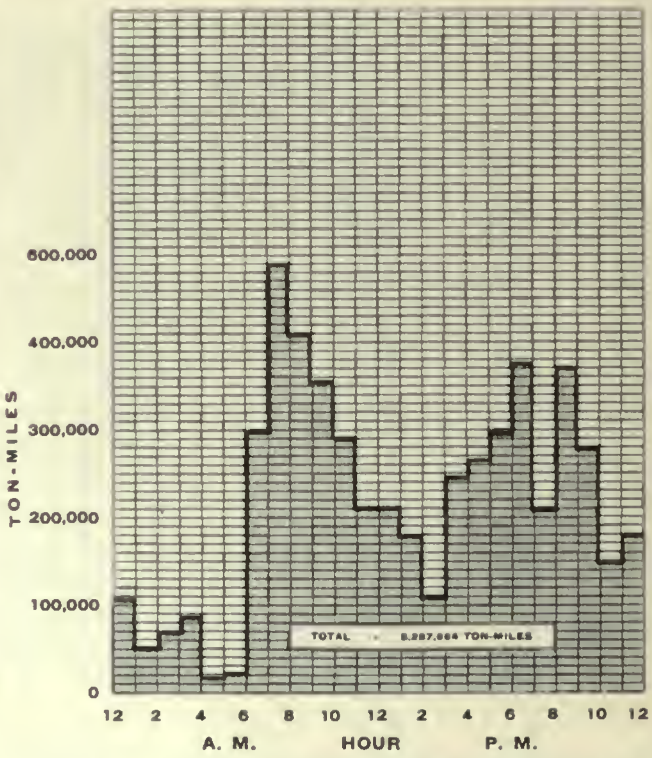


FIG. 414. TRAFFIC DIAGRAM. Ton-Miles for the Average Day for Steam Operation in Through Passenger Service within Area of Investigation.

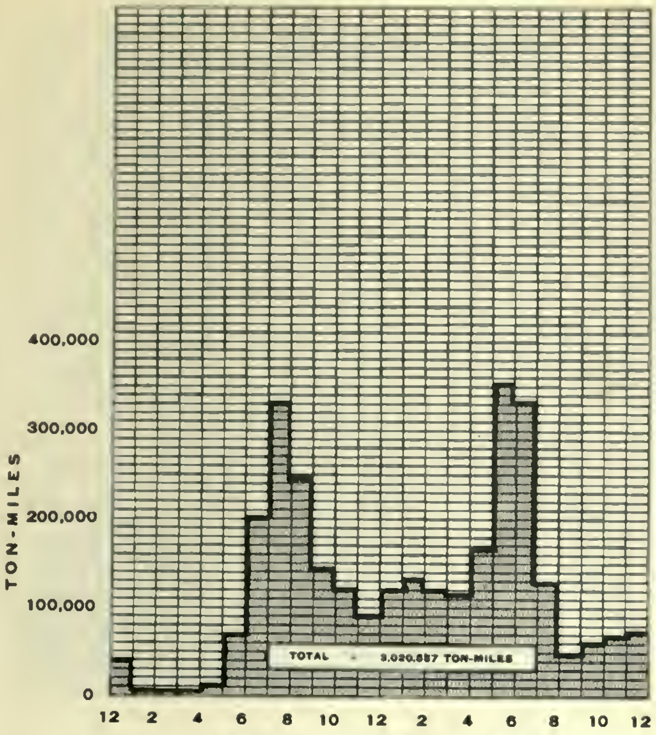


FIG. 415. TRAFFIC DIAGRAM. Ton-Miles for the Average Day for Steam Operation in Suburban Passenger Service within Area of Investigation.

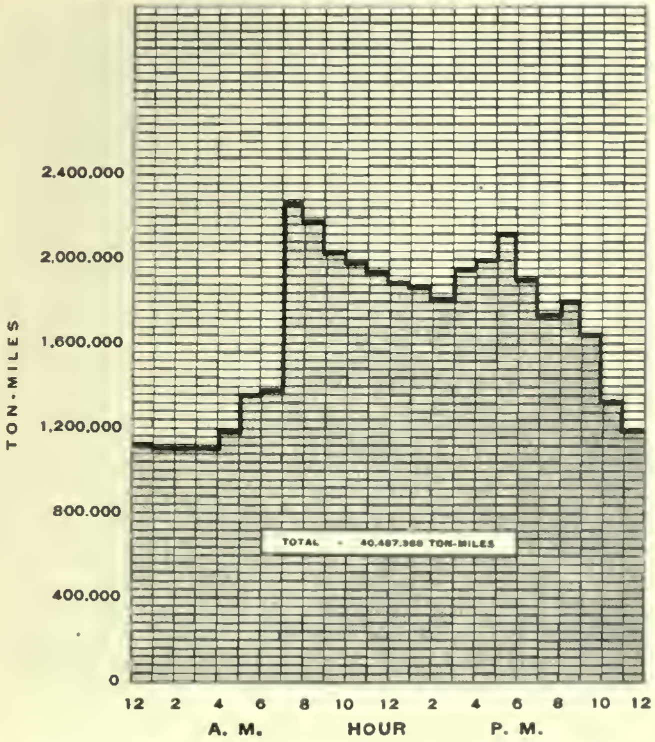


FIG. 416. TRAFFIC DIAGRAM. Total Ton-Miles for the Average Day for Steam Operation in All Classes of Service within Area of Investigation.

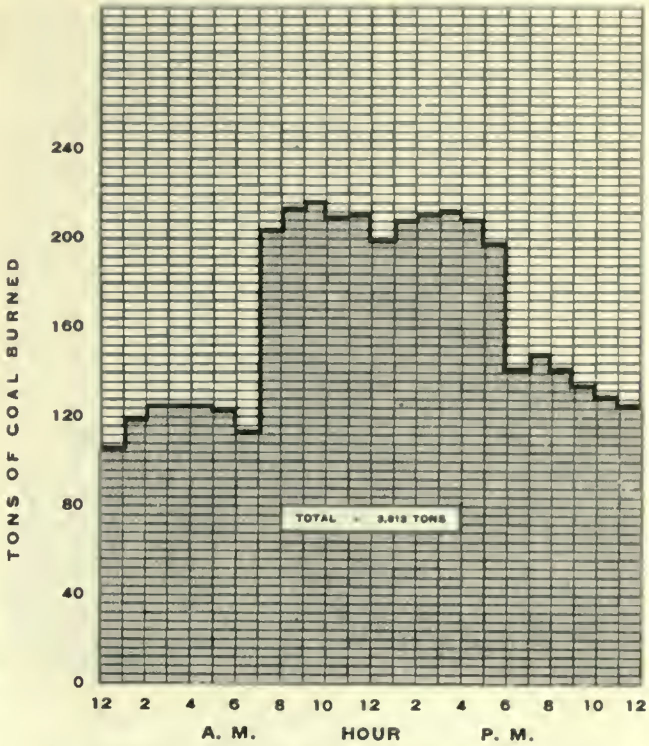


FIG. 417. DIAGRAM OF COAL CONSUMPTION. Tons of Coal Burned during the Average Day for Steam Operation in Yard Switching Service within Area of Investigation.

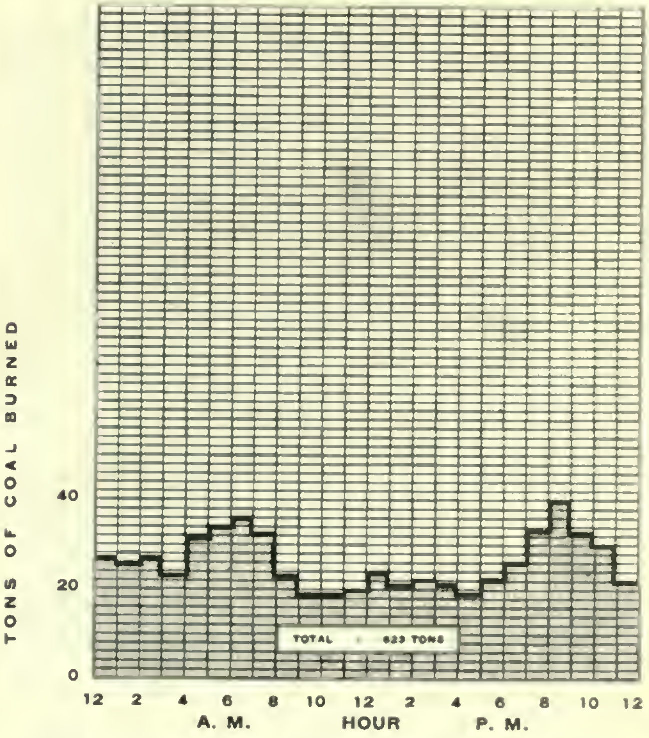


FIG. 418. DIAGRAM OF COAL CONSUMPTION. Tons of Coal Burned during the Average Day for Steam Operation in Road Freight Service within Area of Investigation.

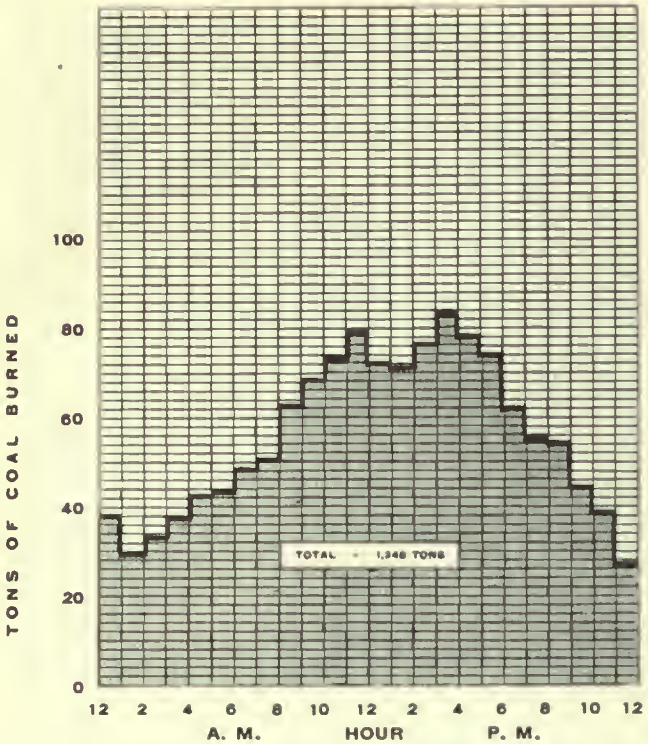


FIG. 419. DIAGRAM OF COAL CONSUMPTION. Tons of Coal Burned during the Average Day for Steam Operation in Freight Transfer Service within Area of Investigation.

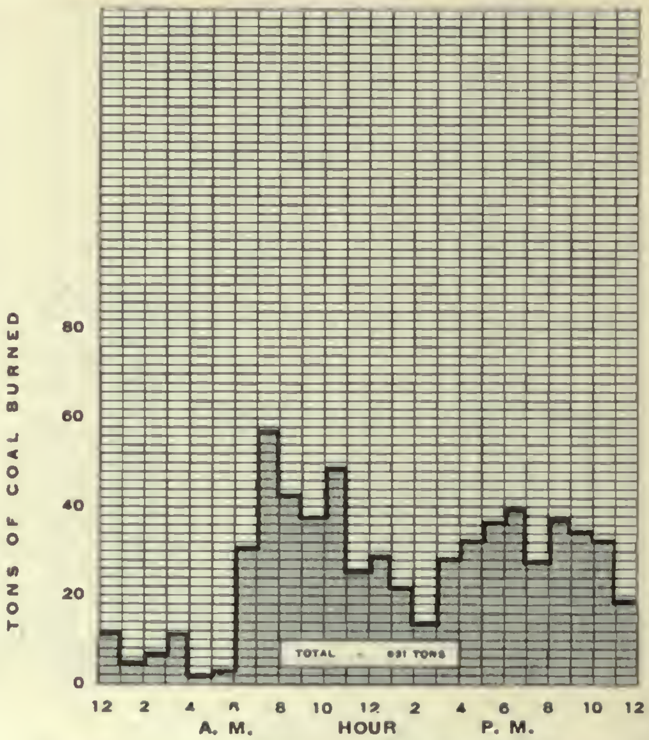


FIG. 421. DIAGRAM OF COAL CONSUMPTION. Tons of Coal Burned during the Average Day for Steam Operation in Through Passenger Service within Area of Investigation.

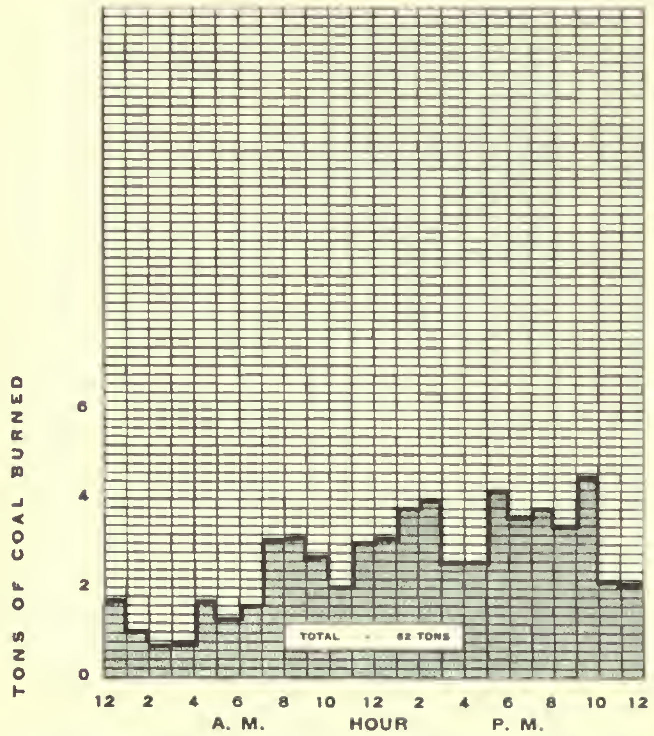


FIG. 420. DIAGRAM OF COAL CONSUMPTION. Tons of Coal Burned during the Average Day for Steam Operation in Passenger Transfer Service within Area of Investigation.

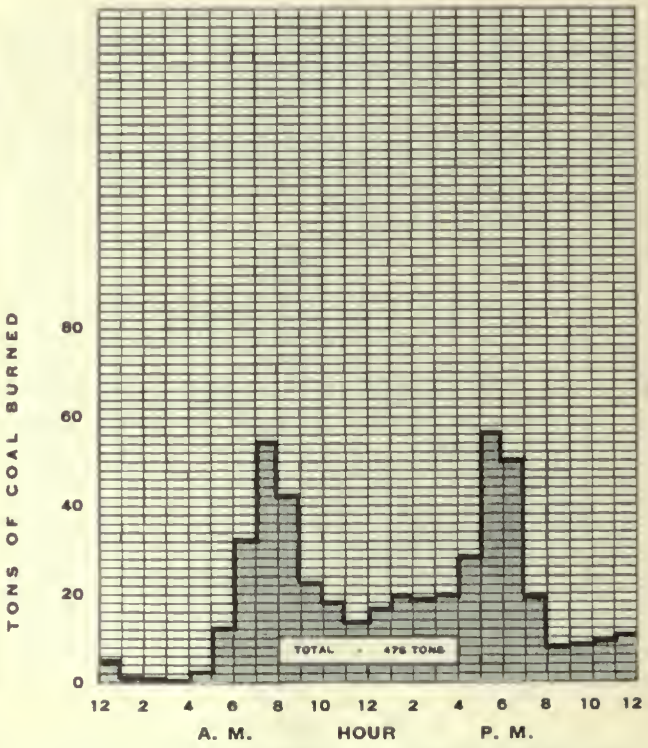


FIG. 422. DIAGRAM OF COAL CONSUMPTION. Tons of Coal Burned during the Average Day for Steam Operation in Suburban Passenger Service within Area of Investigation.

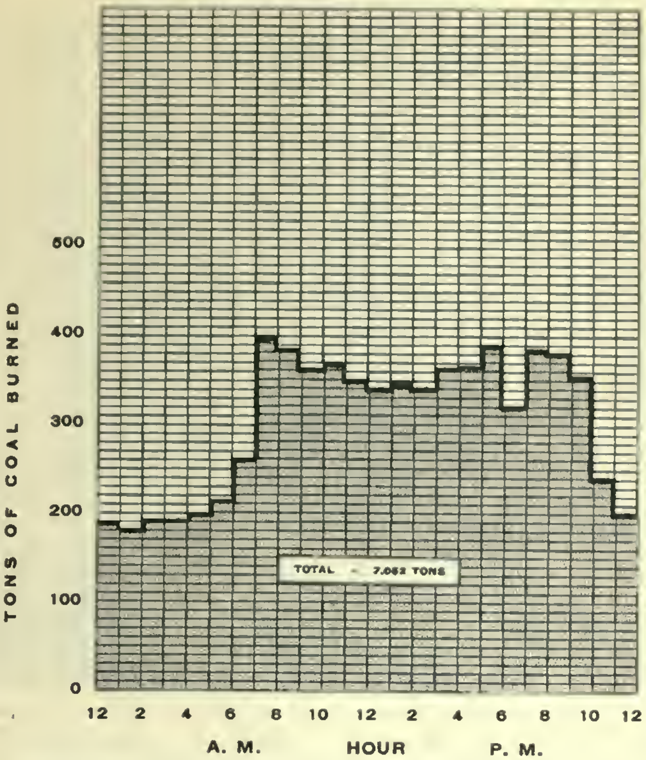


FIG. 423. DIAGRAM OF COAL CONSUMPTION. Total Tons of Coal Burned during the Average Day for Steam Operation in All Classes of Service within Area of Investigation.

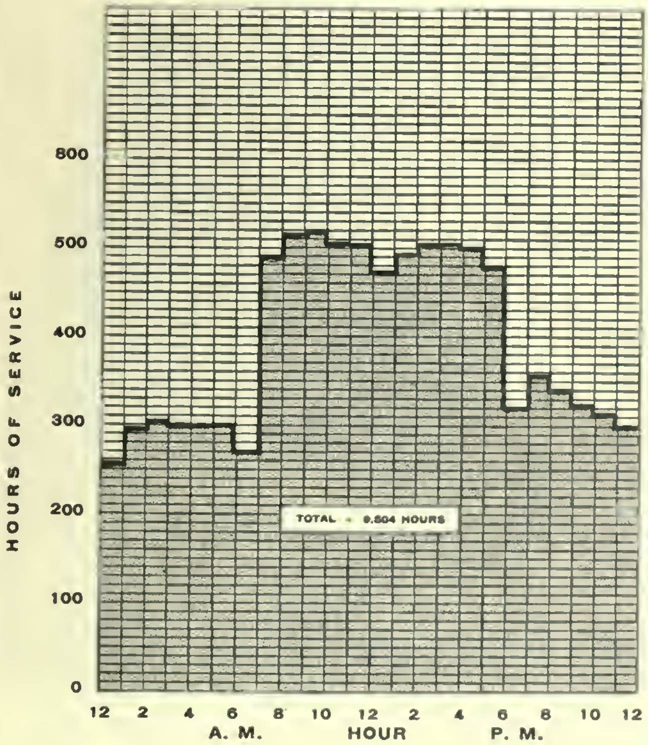


FIG. 424. TRAFFIC DIAGRAM. Locomotive-Hours of Service for the Average Day for Steam Operation in Yard Switching Service within Area of Investigation.

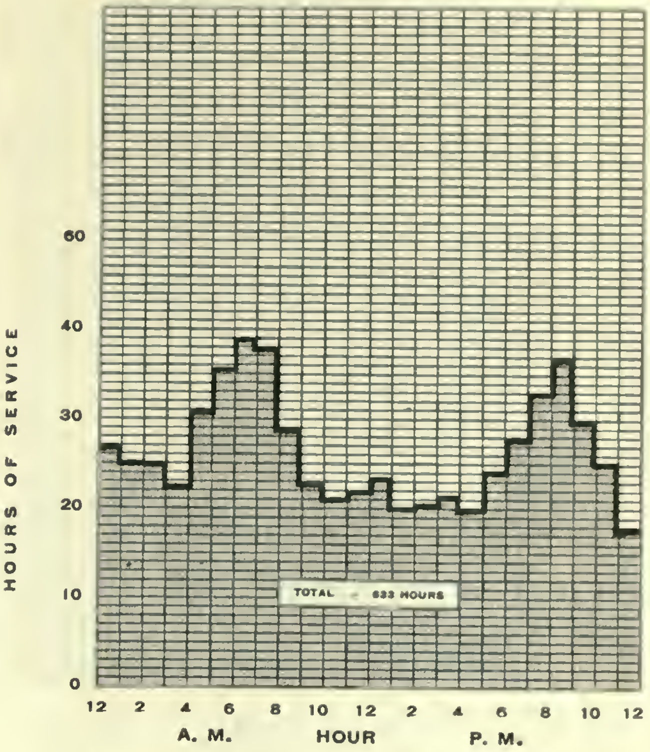


FIG. 425. TRAFFIC DIAGRAM. Locomotive-Hours of Service for the Average Day for Steam Operation in Road Freight Service within Area of Investigation.

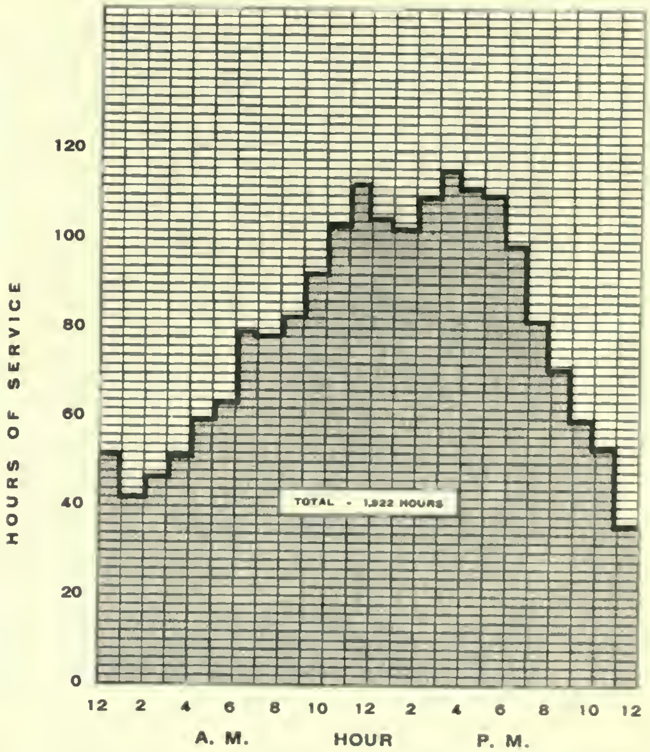


FIG. 426. TRAFFIC DIAGRAM. Locomotive-Hours of Service for the Average Day for Steam Operation in Freight Transfer Service within Area of Investigation.

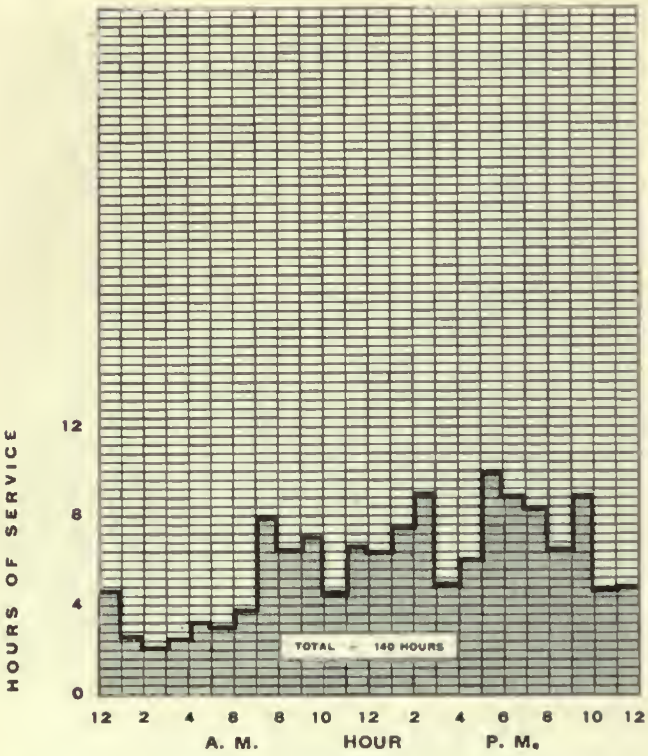


FIG. 427. TRAFFIC DIAGRAM. Locomotive-Hours of Service for the Average Day for Steam Operation in Passenger Transfer Service within Area of Investigation.

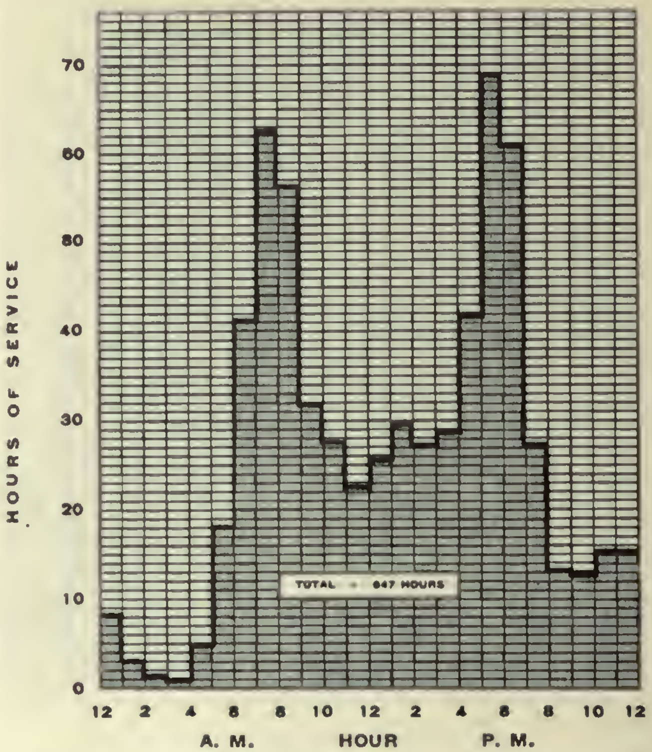


FIG. 429. TRAFFIC DIAGRAM. Locomotive-Hours of Service for the Average Day for Steam Operation in Suburban Passenger Service within Area of Investigation.

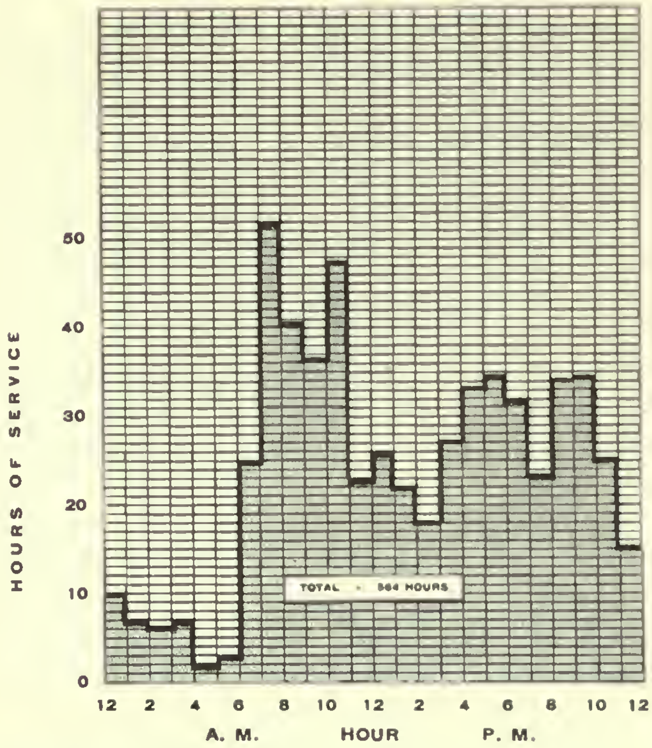


FIG. 428. TRAFFIC DIAGRAM. Locomotive-Hours of Service for the Average Day for Steam Operation in Through Passenger Service within Area of Investigation.

FIG. 430. TRAFFIC DIAGRAM. Total Locomotive-Hours of Service for the Average Day for Steam Operation in All Classes of Service within Area of Investigation.

TABLE CLXXVII. SUMMARY OF RESULTS OF YARD LOCOMOTIVE TESTS

Railroad	No. of Tests	Duration of Tests Hours*	Time		Distance Miles	Mi. per Hr. while in Motion	Trailing Load Tons		Loco. and Average Trailing Load Tons †	Ton-Miles		No. of Stops	Average Length of Run Feet
			Motion Per Cent	Standing, Per Cent			Avg.	Max.		Cars	Cars and Loco.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Atchison, Topeka & Santa Fe Ry.	3	20.52	68.93	31.07	76.94	5.4	191	1,400	293	14,716	22,533	317	1,282
Baltimore & Ohio Chicago Terminal R. R.	6	54.94	66.27	33.73	160.92	4.1	377	2,450	476	60,720	76,547	1,614	526
Chicago & Eastern Illinois R. R.	2	19.43	52.90	47.10	58.08	5.6	408	3,300	537	23,704	31,162	780	393
Chicago & North Western Ry.	19	133.34	62.38	37.62	376.48	4.5	298	2,650	408	112,114	153,790	4,835	411
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	5	35.78	77.07	22.93	181.60	6.6	273	1,550	389	49,640	70,691	303	3,165
Chicago, Burlington & Quincy R. R.	4	31.96	66.01	33.99	108.66	5.1	280	2,000	378	30,454	41,086	344	1,668
Chicago Junction Ry.	8	52.01	67.65	32.30	185.38	5.3	243	2,250	356	45,056	65,931	618	1,584
Chicago, Milwaukee & St. Paul Ry.	4	24.89	61.81	38.19	55.08	3.6	425	3,250	527	23,406	29,029	585	498
Chicago, Rock Island & Pacific Ry.	4	29.09	55.29	44.71	97.17	6.0	199	1,160	312	19,166	30,269	788	650
Illinois Central R. R.	5	37.30	72.13	27.87	141.02	5.2	253	1,200	354	35,647	49,980	440	1,692
Indiana Harbor Belt R. R.	8	73.48	62.48	37.52	309.02	6.7	381	3,250	512	117,668	158,077	3,266	499
Lake Shore & Michigan Southern Ry.	6	48.94	60.42	39.58	175.54	5.9	238	1,900	357	41,862	62,389	1,567	592
Pennsylvania Lines	29	245.84	50.33	49.67	678.68	5.5	329	1,890	463	222,947	314,385	6,596	548
Totals	103	807.42	60.12	39.88	2,604.57	5.4	306	3,300	425	797,100	1,106,069	22,053	628‡

* With the exception of 10 tests (Nos. 311 to 320 inc.) on the Pennsylvania Lines, the "Duration of Tests" does not include the noon hour. With the exceptions noted, the locomotives were idle during the noon hour.

† Includes weight of tender.

‡ 582 feet, exclusive of the Chicago & Western Indiana Railroad and the Belt Railway of Chicago

TABLE CLXXVIII. SUMMARY OF RESULTS OF ROAD FREIGHT LOCOMOTIVE TESTS

Railroad	No. of Tests	Duration of Tests Hours	Time		Distance Miles	Speed Mi. per Hr.		Trailing Load Tons		Loco. and Average Trailing Load Tons *	Ton-Miles		No. of Stops	Average Length of Run Feet
			Motion Per Cent	Standing, Per Cent		While in Motion	Max.	Avg.	Max.		Cars	Cars and Loco.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Atchison, Topeka & Santa Fe Ry.	4	1.88	93.7	6.3	31.2	17.7	42	1,016	1,500	1,147	31,691	35,787	6	27,456
Chicago & Eastern Illinois R. R.	2	3.07	81.7	18.3	38.0	15.1	33	1,329	1,400	1,478	50,520	56,174	19	10,560
Chicago & North Western Ry.	4	4.57	73.2	26.8	40.4	12.1	31	1,223	3,460	1,396	49,399	56,502	23	9,274
Chicago, Burlington & Quincy R. R.	1	.32	100.0	.0	6.0	19.0	29	1,749	2,350	1,931	10,494	11,586	1	31,680
Chicago, Milwaukee & St. Paul Ry.	5	4.37	78.2	21.8	53.0	15.5	54	1,494	2,210	1,669	79,158	88,447	14	19,989
Illinois Central R. R.	2	2.83	48.7	51.3	15.3	11.1	24	1,836	3,070	2,062	28,082	31,555	9	8,976
Pennsylvania Lines	4	4.93	91.0	9.0	72.4	16.1	46	1,230	1,750	1,400	89,040	101,354	19	20,120
Totals	22	21.97	78.4	21.6	256.3	14.9	54	1,320	3,460	1,488	338,384	381,405	91	14,871

* Includes weight of tender.

TABLE CLXXIX. SUMMARY OF RESULTS OF SUBURBAN PASSENGER LOCOMOTIVE TESTS

Railroad	No. of Tests	Duration of Tests Hours	Time		Distance Miles	Mi. per Hr. while in Motion	Trailing Load Tons		Loco. and Average Trailing Load Tons *	Ton-Miles		No. of Stops	Average Length of Run Miles
			Motion Per Cent	Standing Per Cent			Avg.	Max.		Cars	Cars and Loco.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Baltimore & Ohio Chicago Terminal R. R.	4	6.04	87.4	12.6	90.0	17.0	64	64	161	5,760	14,446	67	1.34
Chicago & Eastern Illinois R. R.	2	1.56	87.0	13.0	37.0	27.2	93	93	185	3,442	6,846	23	1.61
Chicago & North Western Ry.	8	4.47	91.2	8.8	106.2	25.9	138	190	281	14,646	29,891	52	2.04
Chicago & Western Indiana R. R.	5	4.61	82.1	17.9	81.6	21.4	124	360	223	10,156	18,217	102	.80
Chicago, Burlington & Quincy R. R.	6	3.47	91.8	8.2	82.2	25.8	129	244	248	10,589	20,400	52	1.58
Chicago, Milwaukee & St. Paul Ry.	4	3.34	90.1	9.9	63.2	20.9	136	171	229	8,598	14,451	37	1.71
Chicago, Rock Island & Pacific Ry.	6	4.99	88.1	11.9	97.8	21.7	131	178	223	12,844	21,842	92	1.06
Illinois Central R. R.	18	13.93	89.0	11.0	266.4	21.4	91	118	159	24,258	42,560	318	.84
Lake Shore & Michigan Southern Ry.	2	4.38	87.2	12.8	97.2	25.4	137	152	296	13,365	28,723	54	1.80
Pennsylvania Lines	6	7.05	85.7	14.3	148.4	24.5	126	219	238	18,703	35,272	87	1.71
Totals	61	53.84	87.9	12.1	1,070.0	22.6	1,144	360	2,174	122,361	232,648	884	1.21

* Includes weight of tender.

TABLE CLXXX. SUMMARY OF RESULTS OF THROUGH PASSENGER LOCOMOTIVE TESTS

Railroad	No. of Tests	Duration of Tests Hours	Time		Distance Miles	Mi. per Hr. while in Motion	Trailing Load Tons		Loco. and Average Trailing Load Tons *	Ton-Miles		No. of Stops	Average Length of Run Miles
			Motion Per Cent	Standing, Per Cent			Avg.	Max.		Cars	Cars and Loco.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Atchison, Topeka & Santa Fe Ry.	4	2.00	95.0	5.0	51.6	26.9	489	632	677	25,218	34,920	13	3.97
Chicago & Eastern Illinois R. R.	8	7.36	85.2	14.8	151.0	24.1	381	618	540	57,598	81,485	70	2.16
Chicago & North Western Ry.	12	6.29	94.5	5.5	157.4	26.3	317	633	494	49,953	77,832	28	5.62
Chicago, Burlington & Quincy R. R.	2	.77	96.8	3.2	27.4	36.1	611	645	799	16,728	21,879	6	4.57
Chicago, Milwaukee & St. Paul Ry.	8	5.22	94.5	5.5	126.4	25.5	407	809	575	51,466	72,621	27	4.68
Chicago, Rock Island & Pacific Ry.	4	2.37	89.7	10.3	62.8	29.4	273	408	448	17,129	28,143	17	3.69
Illinois Central R. R.	10	7.63	83.0	17.0	173.8	27.3	348	546	527	60,501	91,563	71	2.45
Lake Shore & Michigan Southern Ry.	8	7.35	83.7	16.3	186.4	30.1	440	817	639	81,946	119,041	43	4.33
Pennsylvania Lines	6	6.22	90.0	10.0	149.6	26.6	383	564	549	57,271	82,116	28	5.34
Totals	62	45.21	88.5	11.5	1,086.4	27.1	385	817	561	417,810	609,602	303	3.58

* Includes weight of tender.

TABLE CLXXXI. SUMMARY OF RESULTS OF FREIGHT AND PASSENGER TRANSFER LOCOMOTIVE TESTS

Railroad	No. of Tests	Service	Duration of Tests Hours	Time		Distance Miles	Mi. per Hr. while in Motion	Trailing Load Tons		Loco. and Average Trailing Load Tons *	Ton Miles		No. of Stops	Average Length of Run Feet
				Motion Per Cent	Standing Per Cent			Avg.	Max.		Cars	Cars and Loco.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Atchison, Topeka & Santa Fe Ry.	6	Freight	9.05	60.2	39.8	43.05	7.9	722	1,370	852	31,098	36,662	100	2,273
Baltimore & Ohio Chicago Terminal R. R.	3	"	12.39	68.3	31.7	79.13	9.3	1,799	2,700	1,962	142,390	155,221	62	6,739
Chicago & Eastern Illinois R. R.	4	"	12.30	66.0	34.0	65.28	8.0	1,389	3,000	1,582	90,667	103,295	214	1,611
Chicago & North Western Ry.	6	"	7.18	71.6	28.4	37.49	7.3	1,397	3,000	1,550	52,376	58,115	42	4,713
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	1	"	3.60	67.8	32.2	18.79	7.7	2,260	2,290	2,381	42,465	44,739	16	6,201
Chicago, Burlington & Quincy R. R.	5	"	11.07	55.8	44.2	43.68	7.1	1,180	2,580	1,379	51,554	60,253	70	3,295
Chicago, Milwaukee & St. Paul Ry.	4	Freight & Passenger	16.83	58.3	41.7	67.52	6.9	1,116	2,090	1,276	75,353	86,213	287	1,242
Chicago, Rock Island & Pacific Ry.	4	Freight	8.17	65.3	34.7	45.34	8.5	1,365	2,110	1,538	61,885	69,735	46	5,204
Illinois Central R. R.	4	"	10.78	73.2	26.8	53.74	6.8	1,598	3,110	1,766	85,877	94,906	61	4,652
Indiana Harbor Belt R. R.	5	"	10.95	79.5	20.5	116.92	13.4	2,048	3,500	2,229	239,429	260,666	95	6,498
Lake Shore & Michigan Southern Ry.	13	Freight & Passenger	16.51	65.7	34.3	94.73	8.7	961	3,130	1,090	90,994	103,263	184	2,719
Pennsylvania Lines	3	Freight	29.38	64.9	35.1	123.36	6.5	568	2,900	717	70,070	88,400	922	706
Totals	58		148.21	65.7	34.3	789.03	8.1 †	1,311	3,500	1,472	1,034,158	1,161,468	2,098	1,986 ‡

* Includes weight of tender.

† 8.6 Mi. per Hr., exclusive of Pennsylvania Lines.

‡ 2,989 feet, exclusive of Pennsylvania Lines.

in feet was brought down to 1,986 by a single road having an average of only 706 feet; otherwise the average would have been 2,989 feet.

Table CLXXIX, a summary of suburban passenger train tests, gives the record of 61 periods of observation on 10 railroads. The percentage of time in motion varied from 82.1 to 91.8, with an average percentage of 87.9. The average speed while in motion varied from 17.0 to 27.2 miles an hour on average lengths of run of from 0.80 to 2.04 miles, total average 1.21 miles. Average trailing loads varied from a minimum of 64 tons to a maximum of 138 tons. The maximum trailing load noted was 360 tons, and this occurred on the road having the shortest average length of run.

Table CLXXX, a summary of the results of observations on through passenger trains, covers 62 tests on 9 railroads. The percentage of the entire observation period during which the trains were in motion varied from 83.0 to 96.8 and the average speed while in motion varied from 24.1 to 36.1 miles per hour. The average lengths of run varied from 2.16 miles to 5.62 miles, and the average trailing loads from a minimum of 273 tons to a maximum of 611 tons. The maximum trailing load noted during the tests in this service was 817 tons.

202.10 Average Traffic Data from Tests and Reports: From the reports submitted by the railroads on Forms 1 to 5 covering the train movements and locomotive coal consumption for the five observation periods of seven 24-hour days each, or 35 days, the data presented in table CLXXXII have been derived.

The results obtained from a combination of the report and the test records are shown by table CLXXXIII.

The schedule speed and average speed while in motion in yard switching service and freight transfer service are shown in table CLXXXIII and in tables CLXXVII and CLXXIX. For yard switching the results show that the average schedule speed is 3.24 miles per hour and the

TABLE CLXXXII. SUMMARY OF TRAIN MOVEMENTS AND COAL CONSUMED BY STEAM LOCOMOTIVES IN SERVICE WITHIN AREA OF INVESTIGATION *
(Basis of 1912)

Item	Yard Service	Road Freight Service	Freight Transfer Service	Passenger Transfer Service	Passenger Service
1	2	3	4	5	6
Locomotive-hours of service for the average day	8,828	644	1,778	138	1,263
Locomotive-hours of service for the year	3,231,047	235,703	650,748	50,508	462,258
Locomotive-miles for the average day	28,604	6,026	10,127	1,067	23,769
Locomotive-miles for the year	10,469,064	2,205,516	3,706,482	390,522	8,699,454
Ton-miles for the average day	12,173,741	6,927,807	10,380,800	462,731	8,638,068
Ton-miles for the year	426,280,950	242,473,242	363,328,003	16,195,600	302,332,384
Coal consumed for the average day, tons	3,635	665	1,261	59	1,167
Coal consumed for the year, tons	1,330,410	243,390	461,526	21,594	427,122
Coal consumed per locomotive-hour of service, pounds	824	2,065	1,418	855	1,848
Coal consumed per locomotive-mile, pounds	254	221	249	111	98
Coal consumed per 1,000 ton-miles, pounds	597	192	243	255	270

* Based on 35 observation days.

TABLE CLXXXIII. SUMMARY OF RESULTS RELATING TO OPERATION AND TRAFFIC WITHIN AREA OF INVESTIGATION
(Basis of 1912)

Average of 1	Yard Service 2	Road Freight Service 3	Freight Transfer Service 4	Passenger Transfer Service 5	Through Passenger Service 6	Suburban Passenger Service 7
Weight of locomotive including tender and two-thirds capacity of coal and water, tons	119	162	134	118*	174*	103*
Trailing load, tons	306*	988	811	335*	350	167
Speed while in motion, mi. per hr.	5.4*	14.9*	8.1*	7.15*	27.1*	22.6*
Schedule speed, mi. per hr.	3.24*	9.37	5.66	4.82*	19.57	19.00
Ratio of time in motion to time in service, per cent	60.1*	78.4*	65.7*	67.5*	88.5*	87.9*
Length of run, miles	0.119*	2.80*	.376*	.22*	3.58*	1.21*
Weight of car and contents including empties, tons		34.3	34.2		52.5*	27.8*

* Information from tests.

average speed while in motion is 5.4 miles per hour. For freight transfer service the reports of the railroads show the average schedule speed to be 5.66 miles per hour, and in the tests the average speed while in motion was found to be 8.1 miles per hour. The average schedule speed for yard switching and freight transfer services combined, allowing for the relative volume of traffic in each service, is 3.65 miles per hour. It will be noted from these figures that the values established by the Interstate Commerce Commission for yard switching, namely, a speed of 6 miles per hour of service, is much higher than that which obtains on the Chicago terminals in the service defined by the Committee as yard service, and higher also than the speed of the combined yard and freight transfer services as defined by the Committee, which combined services coincide with the yard or switching service as usually understood.

203. GROWTH OF THE CHICAGO RAILROAD TERMINALS

SYNOPSIS: This chapter presents the results of a study of the growth of railroad trackage and railroad traffic in Chicago based upon statistics covering the ten-year period from 1903 to 1912, inclusive. The facts set forth by these statistics have been made the basis of an estimate of the growth which may be expected to take place during the ten-year period subsequent to 1912.

203.01 Growth of the Chicago Terminals, a Factor in the Studies of the Committee: The steam railroads of Chicago as they existed in the year 1912 have been described and their activities discussed in the preceding chapters, 201 and 202. The statistical facts secured by the Committee during that year constitute a voluminous record which could not be completely summarized until the advent of a new year. However, the year 1912 has necessarily continued to be the Committee's statistical year, and the facts determined with reference to that year constitute the basis of all the primary computations to which must be applied the estimated increase in the value of such factors as will be affected by the city's future growth prior to electrification.

The extent and character of the railroad terminals of Chicago have in the past been subject to constant changes to meet the requirements of a community subject to a remarkable rate of growth in population and in commercial and manufacturing activities. These changes have been manifested by a steadily increasing mileage of track, and by an increase in the number of passengers carried and in the tonnage of freight handled.

In determining the cost of the electrification of Chicago's railroad terminals, all initial estimates have been based upon the extent and activities of the railroads as they existed in the year 1912. The costs thus determined, however, can not be assumed to offer an accurate indication of the extent of the investment which will be required at the actual time the work is undertaken. With the mileage of track and the traffic density increasing each year, the actual cost of electrifying the Chicago terminals will depend upon conditions existing at the time of the completion of the program of electrification. To meet this situation it was necessary to fix a definite date upon which the work would presumably begin and a definite date upon which it would end. These assumptions possess no significance aside from the fact that they make definite a factor in the cost of electrification which otherwise would be indeterminate. The assumed program of construction fixes the beginning of the work in the year 1916 and its completion in the year 1922 (section 212.04). It is therefore the chief purpose of that portion of the Committee's investigation which is here reported, to formulate a prediction as to the nature and extent of the activities of the railroads of Chicago at the beginning of the year 1922. The only dependable basis for such a prediction exists in the record of past years. The process involves the determination of the rate of growth during the ten-year period prior to 1912 and the application of that rate to the subsequent ten-year period. It is recognized that any prediction with reference to the future growth of the Chicago terminals, based upon their actual development in the past, may not be entirely satisfactory. While it is practicable to summarize values for a period covered by observed or experimental data, it may be somewhat hazardous to apply a rate of increase to periods beyond that to which the known facts apply. It is, of course, impossible to determine whether the influences which have controlled the rate of growth of the Chicago railroad terminals prior to 1912 will continue unabated during the subsequent ten years. Even in the absence of such knowledge, however, the process described is justified, on the basis of expediency, as being the only logical method which could be employed for the purpose of securing an estimate of the cost of electrification at a definite date in the future.

With this understanding of the limitations which necessarily apply to the factors for use in extending the estimates of the cost of electrifying the steam railroad terminals of Chicago as based upon conditions in 1912, it is proposed to give careful consideration to the important factors of mileage and service requirements by which the extent of the railroad facilities and activities may be measured, and to study the rate of growth which characterized them prior to 1912. The several factors involved are:

1. Track mileage.
2. Passenger traffic:
   - *a.* Through trains.
   - *b.* Suburban trains.
   - *c.* Through passengers.
   - *d.* Suburban passengers.
3. Freight traffic:
   - *a.* Tonnage handled through freight houses.
   - *b.* Number of freight cars received and forwarded.

203.02 **Mileage of Track:** The mileage of track for each railroad within the Area of Investigation for the year 1889, and for each of the years embraced by the period from 1903 to 1912, inclusive, is presented in tables CLXXXIV to CCIII, inclusive.

The classification of tracks employed in these tables, "First Main Track," "Second Main Track" and "Sidings," is identical with that of the tax records of Cook County, Ill., and Lake County, Ind., from which the tables were compiled. Third and other main tracks, and other running tracks which are recognized in the classification of certain railroads, are included in the tables as second main track and sidings. Yard tracks and industrial tracks owned by railroads are classified in the tables as sidings. However, each operating railroad employs its own system of classification, and it is probable that the division of trackage into main tracks and sidings is not entirely consistent. In view of this limitation, only the total trackage is considered in this study of growth.

A summary of the foregoing tables, giving the total mileage of track of all steam railroads within the Area of Investigation for the year 1889 and for each of the years embraced by the period from 1903 to 1912 inclusive, is presented in table CCIV.

In compiling tables CLXXXIV to CCIII, adjustments were made to secure the proper distribution of trackage in Zone A and Zone B, and also to eliminate all trackage lying outside of the Area of Investigation. Zone B, as used in the tables for the year 1889, refers to the territory lying between the boundary line of the Area of Investigation and the city limits of Chicago as existing on May 1 of that year. For all other years the two zones were the same as at the end of the Committee's statistical year, 1912. The railroad mileage in Morgan Park is included in Zone B. The total mileage of tracks herein presented for 1912 does not agree with that appearing in the statement of classified railroad mileage given in chapter 201. The difference in the two statements is due to the fact that the classified mileage covered by the statement presented in chapter 201 includes tracks owned by industries, while the tax records include only the mileage of track owned by railroads. The mileage for 1912 covered by the tax records bears a certain ratio to the actual track mileage as determined by the Committee for the same year. It is reasonable to assume that this ratio will obtain for other years as well as for 1912, and also that no great error will be introduced by assuming that the rate of growth in the actual mileage will be the same as that disclosed by the tax records.

The increase in the mileage of main tracks and sidings for the periods 1889 to 1903, 1903 to 1912 and 1889 to 1912, is presented by zones in table CCV.

During the period from 1889 to 1903, the large increase of mileage in Zone A was attended with a decrease of mileage in Zone B in Illinois and with only a very slight increase in Zone B in Indiana and Illinois. This was the result of an increase in the area of Zone A and a corresponding decrease in the area of Zone B in Illinois, due to an extension of the city limits. On account of this change in the area of the two zones, the figures for the period 1889 to 1903 and for the period 1889 to 1912 are only of secondary interest.

An analysis of the tabulated facts presented in tables CLXXXIV to CCV, inclusive, shows that track mileage within the Area of Investigation increased 38.5 per cent from 1903 to 1912. In Zone B the increase was 67.9 per cent and in Zone A 24.05 per cent.

203.03 **Density of Trackage:** In determining the increase in the density of trackage (miles of

TABLE CLXXXIV. TRACK MILEAGE OF STEAM RAILROADS (FIRST MAIN TRACK) IN ZONE A (THE CITY OF CHICAGO)

Railroad	First Main Track — Miles										
	1889 ††	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.*	1.74	7.37	7.37	7.37	7.37	7.37	7.37	7.37	7.40	7.40	6.01
Baltimore & Ohio R. R.		8.09	8.09	8.09	8.09	8.09	8.09	8.09	8.09	8.09	8.09
Baltimore & Ohio Chicago Terminal R. R.	8.79	17.89	17.70	17.77	17.77	17.77	17.77	17.77	17.77	17.77	17.72
Calumet, Hammond & Southeastern R. R.											1.21
Chesapeake & Ohio Ry. of Indiana											
Chicago & Alton R. R.	6.06	7.12	7.12	7.12	7.12	7.12	7.12	7.12	7.12	7.12	7.12
Chicago & Calumet River R. R.									1.68	1.68	1.68
Chicago & Eastern Illinois R. R.											
Chicago & Erie R. R.											
Chicago & Illinois Western R. R.					0.03	0.03	0.03	2.16	2.16	2.16	2.16
Chicago & North Western Ry.	12.73	34.04	35.26	35.26	35.26	35.44	35.44	35.44	35.44	35.56	35.56
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	7.68	44.25	44.25	44.25	44.25	44.25	44.25	44.25	44.25	44.25	44.25
Chicago, Burlington & Quincy R. R.†	5.47	5.47	5.47	5.47	5.47	5.65	5.65	5.65	5.65	5.65	5.65
Chicago Great Western R. R.											
Chicago, Indiana & Southern R. R.											
Chicago, Indianapolis & Louisville Ry.											
Chicago Junction Ry.		11.91	11.91	11.91	11.91	11.91	11.91	11.57	11.57	11.65	11.31
Chicago, Milwaukee & St. Paul Ry.	7.77	28.85	28.85	28.85	28.85	28.85	28.85	28.87	28.87	28.87	28.87
Chicago River & Indiana R. R.											2.24
Chicago, Rock Island & Pacific Ry.	3.66	18.42	18.42	18.42	18.42	18.42	18.42	18.42	18.42	18.42	18.42
Chicago Short Line Ry.							0.91	0.91	0.91	0.91	0.91
Chicago Union Transfer Ry.		3.44	3.44	3.44	3.44	3.44	3.44	3.44	3.44	3.44	3.44
Chicago, West Pullman & Southern R. R.								1.17	1.17	1.17	1.17
Elgin, Joliet & Eastern Ry.		1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.71	1.71	2.73
Grand Trunk Western Ry.		8.52	8.52	8.52	8.52	8.52	8.52	8.52	8.52	8.52	8.52
Illinois Central R. R.‡	5.06	30.39	30.05	30.05	30.05	29.64	29.64	29.64	29.64	29.64	29.68
Illinois Northern Ry.*			19.79	12.25	12.25	12.15	4.51	4.11	4.11	4.11	4.11
Indiana Harbor Belt R. R.		5.22	5.22	5.22	5.22	5.22	5.34	5.34	5.34	5.34	5.28
Lake Shore & Michigan Southern Ry.		7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61
Manufacturers' Junction Ry.											
Michigan Central R. R.		3.79	3.79	3.79	3.79	3.79	3.97	4.38	3.71	3.71	3.77
Minneapolis, St. Paul & Sault Ste. Marie Ry.											
New York, Chicago & St. Louis R. R. ¶		8.69	8.69	8.69	8.69	8.69	8.69	8.68	7.99	7.99	7.99
Pere Marquette R. R.											
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.§	7.18	19.92	19.92	19.92	19.92	19.92	19.89	19.91	19.94	19.96	19.96
Pittsburgh, Fort Wayne & Chicago Ry.**	3.30	27.26	27.26	27.26	27.26	27.26	27.28	27.30	27.30	27.30	27.70
Pullman Railroad										2.71	2.71
Wabash Railroad		4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92
Totals	69.44	304.93	325.41	317.94	317.97	317.82	311.38	314.40	314.73	317.66	320.79

TABLE CLXXXV. TRACK MILEAGE OF STEAM RAILROADS (SECOND MAIN TRACK) IN ZONE A (THE CITY OF CHICAGO)

Railroad	Second Main Track — Miles										
	1889 ††	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.*		5.75	5.75	5.75	5.91	5.91	5.91	5.91	5.94	5.94	5.93
Baltimore & Ohio R. R.		8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05
Baltimore & Ohio Chicago Terminal R. R.	7.44	16.19	16.19	16.19	16.19	16.19	17.71	17.72	17.72	17.72	17.70
Calumet, Hammond & Southeastern R. R.											
Chesapeake & Ohio Ry. of Indiana											
Chicago & Alton R. R.	5.59				7.12	7.12	7.12	7.12	7.12	7.12	7.12
Chicago & Calumet River R. R.											
Chicago & Eastern Illinois R. R.											
Chicago & Erie R. R.											
Chicago & Illinois Western R. R.											
Chicago & North Western Ry.	11.97	33.30	34.51	34.51	34.51	34.68	34.68	34.68	34.68	34.60	62.78
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	3.19	38.30	38.30	38.30	38.30	38.30	38.30	38.30	38.30	38.30	38.30
Chicago, Burlington & Quincy R. R.†	5.47	5.47	5.47	5.47	5.47	5.65	5.65	5.65	5.65	5.65	16.10
Chicago Great Western R. R.											
Chicago, Indiana & Southern R. R.											
Chicago, Indianapolis & Louisville Ry.											
Chicago Junction Ry.		11.20	11.20	11.20	11.20	11.20	11.20	9.69	10.86	10.86	10.86
Chicago, Milwaukee & St. Paul Ry.	7.21	25.89	25.89	25.89	25.89	25.89	25.89	25.91	25.91	25.91	25.91
Chicago River & Indiana R. R.											0.81
Chicago, Rock Island & Pacific Ry.	3.66	17.71	17.71	17.71	17.71	17.71	17.71	17.71	17.71	17.71	17.71
Chicago Short Line Ry.											
Chicago Union Transfer Ry.		0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Chicago, West Pullman & Southern R. R.											
Elgin, Joliet & Eastern Ry.		1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.71	1.71	2.70
Grand Trunk Western Ry.		8.52	8.52	8.52	8.52	8.52	8.52	8.52	8.52	8.52	8.52
Illinois Central R. R.‡	4.64	26.97	27.01	27.01	27.01	27.01	27.01	27.01	27.01	27.01	27.22
Illinois Northern Ry.*											
Indiana Harbor Belt R. R.		5.03	5.03	5.03	5.03	5.03	5.34	5.34	5.34	5.34	5.28
Lake Shore & Michigan Southern Ry.		7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61
Manufacturers' Junction Ry.											
Michigan Central R. R.	1.41	3.78	3.75	3.78	3.78	3.78	3.96	4.35	3.71	3.71	3.78
Minneapolis, St. Paul & Sault Ste. Marie Ry.											
New York, Chicago & St. Louis R.R.¶							8.65	8.65	8.03	8.03	7.99
Pere Marquette R. R.											
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.§	7.18	17.57	17.57	17.57	17.57	17.57	17.57	17.58	17.61	17.62	17.62
Pittsburgh, Fort Wayne & Chicago Ry.**	2.94	16.99	16.99	16.99	16.99	16.99	16.99	16.96	16.97	16.97	16.97
Pullman Railroad										1.24	1.26
Wabash Railroad				4.93	4.93	4.93	4.92	4.93	4.92	4.92	4.92
Totals	60.70	250.28	251.50	256.40	263.74	264.09	274.74	273.64	273.56	274.73	315.33

* Decrease or increase due to change in classification.
† Increase due to St. Charles Air Line.
‡ Includes charter line which pays no taxes to Cook County.
¶ Decrease due to change in alignment.
§ Includes Englewood Connecting Ry.
** Includes all Pennsylvania R. R. branches except Englewood Connecting Ry.
†† Figures for 1889 include only the territory within the Chicago City Limits May 1, 1889. Morgan Park is not included in Zone A.

TABLE CLXXXVI. TRACK MILEAGE OF STEAM RAILROADS (SIDINGS) IN ZONE A (THE CITY OF CHICAGO)

Railroad	Sidings — Miles										
	1889 ††	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.*	10.09	42.64	38.61	38.79	40.50	43.82	43.17	46.36	47.19	52 20	56.53
Baltimore & Ohio R. R.	2.37	24.96	24.96	24.96	24.96	25.67	25.67	25 73	26.22	26.22	20.22
Baltimore & Ohio Chicago Terminal R. R.	12.58	47.10	47.61	49.35	50.39	50.76	50 48	50.05	49.82	50.57	50.60
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	7.14	5.93
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	......	......	......	......	......	......
Chicago & Alton R. R.	21.39	37.83	31.83	31.83	32.60	32.60	32.63	32.94	33.03	34.22	36.52
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	1.29	1.29	1.29
Chicago & Eastern Illinois R. R.	0.82	12.27	0.70	6.78	6.92	6.95	6.90	0.90	6.90	6 91	0.92
Chicago & Erie R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Illinois Western R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & North Western Ry.	108.51	172.19	174.32	212.51	219.27	220.64	225.14	228.32	231.42	327.58	255.23
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	23.59	115.74	135.30	135.30	144.06	166.06	166.07	167.07	168.06	182.59	198.20
Chicago, Burlington & Quincy R. R.†	66.07	76.40	78.38	84.00	84.00	80.17	84.97	86.61	102.85	90.18	84.37
Chicago Great Western R. R.	......	5.89	15.91	15.93	16.07	16.07	20.05	20.05	11.05	11.48	11.60
Chicago, Indiana & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Indianapolis & Louisville Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Junction Ry.	......	111.43	119.17	123.73	132.24	133.57	135.98	112·06	116.42	120.12	125.09
Chicago, Milwaukee & St. Paul Ry.	54.91	117.59	117.43	118.95	123.69	125.74	120.74	128.03	144.82	145.85	146.28
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	1.07
Chicago, Rock Island & Pacific Ry.	15.32	75.17	75.17	76.04	76.04	76.99	70.99	77.01	78.59	79.70	79.62
Chicago Short Line Ry.	......	......	......	......	......	......	3.21	3.21	3.21	3.21	3.21
Chicago Union Transfer Ry.	......	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.94	3.09
Chicago, West Pullman & Southern R. R.	......	1.54	1.54	1.54	1.54	1.54	0.99	0.89	0.89	0.89	0.89
Elgin, Joliet & Eastern Ry.	......	14.94	13.59	14.84	14.84	15.73	15.73	15.73	15.37	15.37	15.30
Grand Trunk Western Ry.	......	26.25	26.25	26.25	26.25	20.25	24 94	25.06	25.09	25.34	29.07
Illinois Central R. R.‡	59.42	195.31	225.03	226.50	229.33	233.02	237.03	239.17	240.15	251.34	251.55
Illinois Northern Ry.*	......	......	......	......	......	......	......	2.32	5.75	5.75	5.75
Indiana Harbor Belt R. R.	......	......	......	......	......	......	1.74	1.74	1.88	2.07	3.83
Lake Shore & Michigan Southern Ry.	12.19	70.34	72.42	73.03	72.98	73.85	75.13	74.62	75.29	75.48	76.57
Manufacturers' Junction Ry.	......	......	......	......	......	1.16	1.04	0.92	0.92	0.63	0.63
Michigan Central R. R.	......	42.36	42.53	42.60	42.60	42.60	43.05	45.01	40.70	46.70	47.61
Minneapolis, St. Paul & Sault Ste. Marie Ry.	......	......	......	......	......	......	......	......	......	......	......
New York, Chicago & St. Louis R. R.¶	0.30	24.71	26.78	28.23	29.13	29.55	26.98	20.94	25.99	25.99	26.35
Pere Marquette R. R.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.§	22.73	61.46	64.81	67.15	69.92	74.23	80.31	79.92	81.12	81.10	80.63
Pittsburgh, Fort Wayne & Chicago Ry.**	14.92	79.15	84.32	81.12	94.82	89.96	89.39	90.71	90.10	97.57	99.93
Pullman Railroad	......	......	......	......	......	......	......	......	......	2.58	2.58
Wabash Railroad	......	19.90	22.57	23.02	28.68	28.68	28.68	28.68	28.67	28.68	28.67
Totals	426.41	1,377 85	1,447.91	1,505.13	1,563.45	1,604.23	1,625.63	1,019.90	1,667.41	1,801.69	1,761.73

TABLE CLXXXVII. TRACK MILEAGE OF STEAM RAILROADS (MAIN TRACK AND SIDINGS) IN ZONE A (THE CITY OF CHICAGO)

Railroad	Main Track and Sidings — Miles										
	1889 ††	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.*	12.43	55.76	51.73	51.91	53.78	57.10	56.45	59.64	60.53	65.54	68.47
Baltimore & Ohio R. R.	2.37	41.10	41.10	41.10	41.10	41.81	41.81	41.87	42.36	42.36	42.36
Baltimore & Ohio Chicago Terminal R. R.	28.81	81.24	81.50	83.31	84.35	84.72	85.90	86.14	85.31	86.06	86.02
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	7.14	7.14
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	......	......	......	......	......	......
Chicago & Alton R. R.	33.04	44.95	38.95	38.95	46.84	46.84	46.87	47.18	47.27	48.46	50.76
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	2.97	2.97	2.97
Chicago & Eastern Illinois R. R.	0.82	12.27	6.76	6.78	6.92	6.95	6.90	6.90	6.90	0.91	6.92
Chicago & Erie R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Illinois Western R. R.	......	......	......	......	0.03	0.03	0.03	2.16	2.10	2.10	2 16
Chicago & North Western Ry.	133.21	239.53	244.09	282.28	289.04	296.76	295.26	298.44	301.54	397.74	353.57
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	34.46	198.29	217.85	217.85	226.61	248.61	248.62	249.62	250.61	265.14	280.75
Chicago, Burlington & Quincy R. R.†	77.61	87.34	89.32	94.94	94.94	91.47	96.27	97.91	114.15	101.48	106.12
Chicago Great Western R. R.	......	5.89	15.91	15.93	16.07	16.07	20.05	20.05	11.05	11.48	11.60
Chicago, Indiana & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Indianapolis & Louisville Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Junction Ry.	......	134.54	142.28	146.84	155.35	156.68	159.09	133.32	138.85	142.63	147.86
Chicago, Milwaukee & St. Paul Ry.	69.89	172.33	172.17	173.69	178.43	180.48	181.48	182.81	199.60	200.63	201.06
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	4.12
Chicago, Rock Island & Pacific Ry.	22.64	111.30	111.30	112.17	112.17	113.12	113.12	113.17	114.72	115.83	115.75
Chicago Short Line Ry.	......	......	......	......	......	......	4.12	4.12	4.12	4.12	4.12
Chicago Union Transfer Ry.	......	0.25	6.25	6.25	6.25	6.25	6.25	0.25	6.25	6.57	6.72
Chicago, West Pullman & Southern R. R.	......	1.54	1.54	1.54	1.54	1.54	0.99	2.06	2.06	2.06	2.06
Elgin, Joliet & Eastern Ry.	......	18.46	17.11	18.36	18.36	19.25	19.25	19.25	18.79	18.79	20.73
Grand Trunk Western Ry.	......	43.29	43.29	43.29	43.29	43.29	41.98	42.10	42.13	42.38	46.11
Illinois Central R. R.‡	69.12	252.67	282.09	283.02	286.39	289.67	293.68	295.82	296.80	307.99	308.45
Illinois Northern Ry.*	......	......	19.79	12.25	12.25	12.15	4.51	6.43	9.86	9.86	9.86
Indiana Harbor Belt R. R	......	10.25	10.25	10.25	10.25	10.25	12.42	12.42	12.56	12.75	14 30
Lake Shore & Michigan Southern Ry.	12.19	85.56	87.64	88.25	88.20	89.07	90.35	89.84	90.51	90.70	91.79
Manufacturers' Junction Ry.	......	......	......	......	......	1.16	1.04	0.92	0.92	0.63	0 63
Michigan Central R. R.	1.41	49.93	50.07	50.17	50.17	50.17	50.98	54.34	54.12	54.12	55.16
Minneapolis, St. Paul & Sault Ste. Marie Ry.	......	......	......	......	......	......	......	......	......	......	......
New York, Chicago & St. Louis R. R.¶	0.30	33.40	35.47	36.92	37.82	38.24	44.32	44.27	42.01	42.01	42.33
Pere Marquette R. R.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.§	37.09	98.95	102.30	104.64	107.41	111.72	117.77	117.41	118 67	118 68	118 21
Pittsburgh, Fort Wayne & Chicago Ry.**	21.16	123.40	128.57	125.37	139.07	134.21	133.66	134.97	140.37	141.84	114 60
Pullman Railroad	......	......	......	......	......	......	......	......	......	6.53	6.55
Wabash Railroad	......	24.82	27.49	32.87	38.53	38.53	38.52	38 53	38.51	38 52	38 51
Totals	556 55	1,933 06	2,024.82	2,079.53	2,145.16	2,186 14	2,211 75	2,207 94	2,255 70	2,394 08	2,397.85

* Decrease or increase due to change in classification.

† Increase due to St. Charles Air Line.

‡ Includes charter line which pays no taxes to Cook County.

¶ Decrease due to change in alignment.

§ Includes Englewood Connecting Ry.

** Includes all Pennsylvania R. R. branches except Englewood Connecting Ry.

†† Figures for 1889 include only the territory within the Chicago City Limits May 1, 1889. Morgan Park is not included in Zone A.

TABLE CLXXXVIII. TRACK MILEAGE OF STEAM RAILROADS (FIRST MAIN TRACK) IN ZONE B IN ILLINOIS*

Railroad	First Main Track—Miles										
	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.†	8.36	6.32	6.32	6.32	6.32	6.32	6.32	6.32	6.31	6.31	6.31
Baltimore & Ohio R. R.	5.91	......	......	......	......	......	......	......	......	......	......
Baltimore & Ohio Chicago Terminal R. R.	9.10	40.36	39.29	39.29	39.29	39.28	39.28	39.28	39.28	36.62	35.65
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	......	......	......	......	......	......
Chicago & Alton R. R.	6.62	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Eastern Illinois R. R.	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54
Chicago & Erie R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Illinois Western R. R.	......	......	......	......	6.91	8.14	8.14	8.14	8.14	8.14	8.14
Chicago & North Western Ry.	29.32	15.70	18 50	18.50	18.50	18.50	18.65	18.65	18.65	18.53	18.53
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	40 21	3.11	3.11	3.11	3 11	3.11	3.11	3.11	3.11	3.11	3.11
Chicago, Burlington & Quincy R. R.	8.33	8.33	8.33	8.33	8 33	8.33	8 33	8 33	8.33	8.33	8.33
Chicago Great Western R. R.	4.98	4.98	4.98	4 98	4.98	4.98	4.98	4.98	4.98	4.98	4.98
Chicago, Indiana & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Indianapolis & Louisville Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Milwaukee & St. Paul Ry.	34 51	12.15	12.15	12.15	12.15	12.15	12.15	12.15	12.16	12.16	12.16
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Rock Island & Pacific Ry.	19.52	4.73	4.73	4 73	4.73	4.73	4.73	4.73	4.73	4 73	4.73
Chicago Short Line Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Ry.	......	3.56	3.56	3.56	3 56	3.56	3.56	3.56	3.56	3.56	3 84
Chicago, West Pullman & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Elgin, Joliet & Eastern Ry.	......	......	......	......	......	......	......	......	......	......	......
Grand Trunk Western Ry	21.42	12 82	12 82	12 82	12.82	12.83	12.83	12 83	12.85	12 85	12.85
Illinois Central R. R.¶	27.86	14 05	14.14	14 14	14.14	14.14	14.14	14 14	14.14	14 14	14.14
Illinois Northern Ry.	......	......	......	......	......	......	......	......	......	......	......
Indiana Harbor Belt R. R.	......	25.92	25 92	26.20	26.20	26.20	25.86	25.86	25.86	25.86	27.51
Lake Shore & Michigan Southern Ry.	7.61	......	......	......	......	......	......	......	......	......	......
Manufacturers' Junction Ry.	......	......	......	0.86	0.94	1.76	1.76	1.76	1.76	1.76	1.76
Michigan Central R. R.	6.30	3.10	3.07	3 07	3 07	3 07	3.07	3.07	3.34	3.34	3 27
Minneapolis, St. Paul & Sault Ste. Marie Ry.	6.64	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.25	7.25
New York, Chicago & St. Louis R. R.§	9.97	1.28	1.28	1.28	1.28	1.28	1 28	1.28	1.28	1.28	1.28
Pere Marquette R. R.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.**	21.90	9.22	9.22	9 22	9.22	9.22	9.22	9.22	9.22	9.22	9.22
Pittsburgh, Fort Wayne & Chicago Ry.††	25.27	4.71	4.71	4.71	4.71	4.71	4.71	4.72	4.72	4.72	4.72
Pullman Railroad	......	......	......	......	......	......	......	......	......	......	......
Wabash Railroad	9 04	4 15	4 15	4.15	4.15	4.15	4.15	4.15	4 15	4.15	4.15
Totals	307.31	190 93	192 81	193 95	200 94	202 99	202.71	202 72	203.01	200 13	201.02

TABLE CLXXXIX. TRACK MILEAGE OF STEAM RAILROADS (SECOND MAIN TRACK) IN ZONE B IN ILLINOIS*

Railroad	Second Main Track—Miles										
	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.†	......	......	......	0.32	6 32	6.32	6 32	6.32	6.31	6.31	6.31
Baltimore & Ohio R. R.	5 87	......	......	......	......	......	......	......	......	......	......
Baltimore & Ohio Chicago Terminal R. R.	7.30	18.39	21.91	23.88	23.90	24.79	28.56	27.14	27.14	27.14	25.28
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	......	......	......	......	......	......
Chicago & Alton R. R.	6 62	5.55	5.55	5 55	5.55	5.55	5.55	5.55	5.55	5 55	5.55
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Eastern Illinois R. R.	3.54	3.55	3.55	3 55	3.55	3.55	3.55	3.55	3.55	3.55	3.55
Chicago & Erie R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Illinois Western R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & North Western Ry.	29 32	15.71	18 58	18.58	18 58	18.58	18.65	18.65	18.65	18.54	39.61
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	27.92	3.11	3.11	3.11	3 11	3.11	3.11	3.11	3.11	3.11	3.11
Chicago, Burlington & Quincy R. R.‡	8.33	8.33	8 33	8.33	8.33	8.33	8.33	8 33	8.33	8.33	16 67
Chicago Great Western R. R.	......	......	......	......	......	......	......	0.06	0.82	4 98	4.98
Chicago, Indiana & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Indianapolis & Louisville Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Milwaukee & St. Paul Ry.	17.92	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.67	11.67	11.68
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Rock Island & Pacific Ry.	13 52	4 73	4.73	4.73	4 73	4.73	4.73	4.73	4.73	4 73	4.73
Chicago Short Line Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Ry.	......	3 82	3 82	3.82	3 82	3.82	3.82	3.82	3.82	3.82	3.86
Chicago, West Pullman & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Elgin, Joliet & Eastern Ry.	......	......	......	......	......	......	......	......	......	......	......
Grand Trunk Western Ry.	3.82	12 82	12.82	12.82	12.84	12.84	12 82	12.82	12.82	12.82	12.82
Illinois Central R. R.¶	20.21	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	7.69
Illinois Northern Ry.	......	......	......	......	......	......	......	......	......	......	......
Indiana Harbor Belt R. R.	......	19.80	20 03	20.30	20.30	24.90	23.33	23.33	23.33	23.33	23 84
Lake Shore & Michigan Southern Ry.	7.33	......	......	......	......	......	......	......	......	......	......
Manufacturers' Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Michigan Central R. R.	......	3.10	3 06	3.06	3.06	3.06	5 64	3.06	3.33	3.33	3.25
Minneapolis, St. Paul & Sault Ste. Marie Ry.	......	0.95	3.38	5.40	7.36	7.36	7.36	7.36	7.36	7.25	7 25
New York, Chicago & St. Louis R. R.§	2.32	......	......	......	......	......	1.28	1.28	1.28	1.28	1.28
Pere Marquette R. R.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.**	4 55	9 22	9.22	9.22	9.22	9.22	9.22	9.22	9.22	9.22	9.22
Pittsburgh, Fort Wayne & Chicago Ry.††	10.51	......	......	......	......	......	......	......	......	......	......
Pullman Railroad	......	......	......	......	......	......	......	......	......	......	......
Wabash Railroad	......	......	......	4.15	4 15	4.15	4.15	4.15	4.15	4 15	4.15
Totals	169.18	124.71	133.72	142.45	150.45	155.94	162.05	158.11	159.15	163 09	194 83

* In 1889, "Zone B in Illinois" refers to the territory between the boundary line of the Area of Investigation and the city limits of Chicago as existing May 1, 1889. For all other years the two Zones were the same as at the end of the Committee's statistical year, 1912. Morgan Park is included in Zone B.

Decrease or increase due to change in classification.

‡ Increase due to St. Charles Air Line.

¶ Includes charter line which pays no taxes to Cook County.

§ Decrease due to change in alignment.

** Includes Englewood Connecting Ry.

†† Includes all Pennsylvania R. R. branches except Englewood Connecting Ry.

TABLE CXC. TRACK MILEAGE OF STEAM RAILROADS (SIDINGS) IN ZONE B IN ILLINOIS*

Railroad	Sidings—Miles										
	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.†	17.25	1 92	1.90	1.94	2.21	2.67	2.52	2.52	2.57	2.56	2.04
Baltimore & Ohio R. R.	17.53										
Baltimore & Ohio Chicago Terminal R. R.	11.32	22.99	22.77	30.40	33.36	34.13	33.08	33.50	31.67	34.02	37.75
Calumet, Hammond & Southeastern R. R.											
Chesapeake & Ohio Ry. of Indiana											
Chicago & Alton R. R.	0.25	0.21	1.46	1.47	1.48	1.48	1.48	1.45	1.48	13.43	19.31
Chicago & Calumet River R. R.											
Chicago & Eastern Illinois R. R.	16.08	31.07	31.51	31.58	60.31	60.58	62.00	62.36	62.36	62.36	62.51
Chicago & Erie R. R.											
Chicago & Illinois Western R. R.					1.68	2.09	2.40	2.31	2.31	2.31	2.31
Chicago & North Western Ry.	10.23	11.58	14.72	22.17	51.71	52.40	41.43	42.09	45.70	60.56	76.84
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	58.91	10.01	10.01	9.58	11.97	11 97	11.97	11.97	11.97	11.97	12.91
Chicago, Burlington & Quincy R. R.‡	25.98	55.18	55.80	53.14	53.35	61.95	62.24	62.25	64.73	65.50	69.96
Chicago Great Western R. R.	0.91	1.92	2.06	1.97	1.97	1.97	2.14	4.02	4.27	5.28	5.28
Chicago, Indiana & Southern R. R.											
Chicago, Indianapolis & Louisville Ry.											
Chicago Junction Ry.											
Chicago, Milwaukee & St. Paul Ry.	14.92	8.70	8.31	10.00	9.89	10.27	11.21	12.23	8.73	50.62	51.59
Chicago River & Indiana R. R.											
Chicago, Rock Island & Pacific Ry.	45.49	41.45	41.65	41.95	41.95	41.94	41.95	41.93	41.93	42.92	42.92
Chicago Short Line Ry.											
Chicago Union Transfer Ry.		84.82	84.82	84.82	84.82	84.82	84.82	84.82	84.82	84.82	84.51
Chicago, West Pullman & Southern R. R.											
Elgin, Joliet & Eastern Ry.		7.66	7.66	7.66	7.82	7.72	7.72	7.72	7.66	7.66	7.68
Grand Trunk Western Ry.	23.77	7.87	7.87	7.87	7.87	7.87	7.87	7.85	7.85	7.74	8.15
Illinois Central R. R.¶	10.48	11.93	18.49	18.49	18.60	18.60	18.68	18.77	19.31	19.31	18.83
Illinois Northern Ry.											
Indiana Harbor Belt R. R.		23.78	24.16	24.47	24.08	27.15	23.82	23.83	24.26	24.99	47.59
Lake Shore & Michigan Southern Ry.	33.51										
Manufacturers' Junction Ry.				0.28	1.32	3.93	4.00	4.00	4.00	3.58	3.59
Michigan Central R. R.	9.02	4.55	4.53	4.55	4.53	4.53	4.77	8.26	5.70	5.70	5.57
Minneapolis, St. Paul & Sault Ste. Marie Ry.	1.39	9.54	9.89	9.91	10.47	10.47	10.41	10.47	11.92	16.95	17.30
New York, Chicago & St. Louis R. R.§	13.11	1.46	1.46	1.46	1.46	2.57	2.17	2.21	2.13	2.13	2.17
Pere Marquette R. R.									2.17	8.62	8.62
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.**	7.71	3.67	3.37	4.01	3.90	4.03	3.96	4.92	4.70	4.86	4.92
Pittsburgh, Fort Wayne & Chicago Ry.††	25.94	2.69	2.69	2.80	2.80	2.93	2.72	2.78	2.66	2.80	2.74
Pullman Railroad											
Wabash Railroad	6.36	1.78	1.73	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.14
Totals	350.16	344.78	356.86	373.02	439.78	458.30	445.59	454.49	457 13	542.92	587.23

TABLE CXCI. TRACK MILEAGE OF STEAM RAILROADS (MAIN TRACK AND SIDINGS) IN ZONE B IN ILLINOIS*

Railroad	Main Track and Sidings—Miles										
	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.†	25.61	8.24	8.22	8.58	14.85	15.31	15.16	15.16	15.19	15.18	14.66
Baltimore & Ohio R. R.	29.31										
Baltimore & Ohio Chicago Terminal R. R.	27.72	81.74	83.97	93.57	96.55	98.20	100.92	99.92	98.09	97.78	98.68
Calumet, Hammond & Southeastern R. R.											
Chesapeake & Ohio Ry. of Indiana											
Chicago & Alton R. R.	13.49	11.31	12.56	12.57	12.58	12.58	12.58	12.55	12.58	24.53	30.41
Chicago & Calumet River R. R.											
Chicago & Eastern Illinois R. R.	23.16	38.16	38.60	38.67	67.40	67.67	69.09	69.45	69.45	69.45	69.60
Chicago & Erie R. R.											
Chicago & Illinois Western R. R.					8.59	10.23	10.54	10.45	10.45	10.45	10.45
Chicago & North Western Ry.	68.87	42.99	51.89	59.34	88.88	89.57	78.73	79.39	83.00	97.63	134.98
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	127.04	16.23	16.23	16.07	18.19	18.19	18.19	18.19	18.19	18.19	19.13
Chicago, Burlington & Quincy R. R.‡	42.64	71.84	72.46	69.80	70.01	78.61	78.90	78.91	81.39	82.16	84.96
Chicago Great Western R. R.	5.89	6.90	7.04	6.95	6.95	6.95	7.12	9.06	10.07	15.24	15.24
Chicago, Indiana & Southern R. R.											
Chicago, Indianapolis & Louisville Ry.											
Chicago Junction Ry.											
Chicago, Milwaukee & St. Paul Ry.	67.35	32.50	32.11	33.80	33.69	34.07	35.01	36.03	32.56	74.45	75.43
Chicago River & Indiana R. R.											
Chicago, Rock Island & Pacific Ry.	78.53	50.91	51.11	51.41	51.41	51.40	51.41	51.39	51.39	52.38	52.38
Chicago Short Line Ry.											
Chicago Union Transfer Ry.		92.20	92.20	92 20	92.20	92.20	92.20	92.20	92.20	92.20	92.21
Chicago, West Pullman & Southern R. R.											
Elgin, Joliet & Eastern Ry.		7.66	7.66	7.66	7.82	7.72	7.72	7.72	7.66	7.66	7.68
Grand Trunk Western Ry.	49.01	33.51	33.51	33.51	33.53	33.54	33.52	33.50	33.52	33.41	33.82
Illinois Central R. R.¶	58.55	29.96	36.61	36.61	36.72	36.72	36.80	36.89	37.43	37.43	40.66
Illinois Northern Ry.											
Indiana Harbor Belt R. R.		69.50	70.11	70.97	70.58	78.25	73.01	73.02	73.45	74.18	98.94
Lake Shore & Michigan Southern Ry.	48.45										
Manufacturers' Junction Ry.				1.14	2.26	5.69	5.76	5.76	5.76	5.34	5.35
Michigan Central R. R.	15.32	10.75	10.66	10.68	10.66	10.66	13.48	14.39	12.37	12.37	12.09
Minneapolis, St. Paul & Sault Ste. Marie Ry.	8.03	17.84	20.62	22.66	25.18	25.18	25.12	25.18	26.63	31.45	31.80
New York, Chicago & St. Louis R. R§	25.40	2.74	2.74	2.74	2.74	3.85	4.73	4.77	4.69	4.69	4.73
Pere Marquette R. R.									2.17	8.62	8.62
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.**	34.16	22.11	21.81	22.45	22.34	22.47	22.40	23.36	23.14	23.30	23.36
Pittsburgh, Fort Wayne & Chicago Ry.††	62.82	7.40	7.40	7.51	7.51	7.64	7.43	7.50	7.38	7.52	7.46
Pullman Railroad											
Wabash Railroad	16.30	5.93	5.88	10.53	10.53	10 53	10.53	10.53	10 53	10 53	10 44
Totals	826.65	660.42	683.39	709 42	791 17	817.23	810 35	815 32	819 29	906 14	983 08

* In 1889, "Zone B in Illinois" refers to the territory between the boundary line of the Area of Investigation and the city limits of Chicago as existing May 1, 1889. For all other years the two Zones were the same as at the end of the Committee's statistical year, 1912. Morgan Park is included in Zone B.

† Decrease or increase due to change in classification.

‡ Increase due to St. Charles Air Line.

¶ Includes charter line which pays no taxes to Cook County.

§ Decrease due to change in alignment.

** Includes Englewood Connecting Ry.

†† Includes all Pennsylvania R. R. branches except Englewood Connecting Ry

TABLE CXCII. TRACK MILEAGE OF STEAM RAILROADS (FIRST MAIN TRACK) IN ZONE B IN INDIANA

Railroad	First Main Track — Miles										
	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry	......	......	......	......	......	......	......	......	......	......	......
Baltimore & Ohio R. R.	11.21	11.21	11.21	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18
Baltimore & Ohio Chicago Terminal R. R.	7.00	12.09	12.71	10.34	10.38	10.38	10.38	10.01	10.01	10.01	10.01
Calumet, Hammond & Southeastern R. R	......	......	......	......	......	......	......	......	......	......	......
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	2.64	2.64	2.64	2.64	2.62	1.46
Chicago & Alton R. R	......	......	......	......	......	......	......	......	......	......	......
Chicago & Calumet River R. R	......	......	......	......	......	......	......	......	......	......	......
Chicago & Eastern Illinois R. R	......	......	......	......	......	......	......	......	......	......	......
Chicago & Erie R. R	4.28	4.28	4.28	4.28	4.25	4.28	4.28	4.28	4.28	4.25	4.28
Chicago & Illinois Western R. R	......	......	......	......	......	......	......	......	......	......	......
Chicago & North Western Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	......	......	......	......	......	......	......	......	......	......	......
Chicago, Burlington & Quincy R. R	......	......	......	......	......	......	......	......	......	......	......
Chicago Great Western R. R	......	......	......	......	......	......	......	......	......	......	......
Chicago, Indiana & Southern R. R	......	4.82	4.88	4.86	4.51	11.86	11.28	13.70	13.70	13.52	13.83
Chicago, Indianapolis & Louisville Ry	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06
Chicago Junction Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago, Milwaukee & St. Paul Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago River & Indiana R. R	......	......	......	......	......	......	......	......	......	......	......
Chicago, Rock Island & Pacific Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago Short Line Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago, West Pullman & Southern R. R	......	......	......	......	......	......	......	......	......	......	......
Elgin, Joliet & Eastern Ry	1.26	19.47	19.47	19.38	19.29	19.29	19.29	21.13	21.31	21.13	21.15
Grand Trunk Western Ry	......	......	......	......	......	......	......	......	......	......	......
Illinois Central R. R	......	......	......	......	......	......	......	......	......	......	......
Illinois Northern Ry	......	......	......	......	......	......	......	......	......	......	......
Indiana Harbor Belt R. R	......	9.21	9.21	8.97	8.97	8.97	9.24	9.24	9.24	9.24	9.13
Lake Shore & Michigan Southern Ry	11.31	11.31	11.31	11.31	17.69	17.69	17.69	17.69	22.62	22.62	23.04
Manufacturers' Junction Ry	......	......	......	......	......	......	......	......	......	......	......
Michigan Central R. R	3.68	3.34	3.34	3.34	3.34	5.09	7.54	7.54	7.54	7.54	7.54
Minneapolis, St. Paul & Sault Ste. Marie Ry	......	......	......	......	......	......	......	......	......	......	......
New York, Chicago & St. Louis R. R	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10
Pere Marquette R. R	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Fort Wayne & Chicago Ry.*	14.37	18.57	18.63	18.63	18.63	19.30	19.36	19.07	19.05	19.04	19.05
Pullman Railroad	......	......	......	......	......	......	......	......	......	......	......
Wabash Railroad	......	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31
Totals	62.27	106.77	107.51	104.76	110.71	123.24	125.35	128.95	134.04	133.62	133.14

TABLE CXCIII. TRACK MILEAGE OF STEAM RAILROADS (SECOND MAIN TRACK) IN ZONE B IN INDIANA

Railroad	Second Main Track — Miles										
	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry	......	......	......	......	......	......	......	......	......	......	......
Baltimore & Ohio R. R.	11.21	11.21	11.21	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18
Baltimore & Ohio Chicago Terminal R. R.	......	......	......	......	......	0.19	0.19	0.19	0.27	0.27	0.27
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	......	......	......	......	......	......
Chicago & Alton R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Eastern Illinois R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Erie R. R.	......	......	......	......	2.26	2.26	2.26	2.26	2.26	2.82	2.89
Chicago & Illinois Western R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & North Western Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	......	......	......	......	......	......	......	......	......	......	......
Chicago, Burlington & Quincy R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago Great Western R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Indiana & Southern R. R.	......	4.78	4.84	4.84	3.50	5.44	5.44	5.44	5.44	5.44	5.57
Chicago, Indianapolis & Louisville Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago Junction Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago, Milwaukee & St. Paul Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Rock Island & Pacific Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago Short Line Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Ry	......	......	......	......	......	......	......	......	......	......	......
Chicago, West Pullman & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Elgin, Joliet & Eastern Ry	......	7.71	7.71	7.74	7.74	7.74	7.74	10.41	11.04	11.28	12.59
Grand Trunk Western Ry	......	......	......	......	......	......	......	......	......	......	......
Illinois Central R. R.	......	......	......	......	......	......	......	......	......	......	......
Illinois Northern Ry	......	......	......	......	......	......	......	......	......	......	......
Indiana Harbor Belt R. R.	......	......	......	......	......	......	......	......	......	......	......
Lake Shore & Michigan Southern Ry	......	11.31	11.31	11.31	15.17	15.17	15.15	15.16	16.27	16.27	16.70
Manufacturers' Junction Ry	......	......	......	......	......	......	......	......	......	......	......
Michigan Central R. R.	3.68	3.34	3.34	3.34	3.34	5.09	6.36	7.53	7.54	7.54	7.54
Minneapolis, St. Paul & Sault Ste. Marie Ry	......	......	......	......	......	......	......	......	......	......	......
New York, Chicago & St. Louis R. R.	......	......	......	......	......	......	4.64	4.69	4.69	4.69	4.74
Pere Marquette R. R.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Fort Wayne & Chicago Ry.*	......	11.01	11.01	11.01	11.01	11.01	11.04	11.04	11.04	11.04	11.04
Pullman Railroad	......	......	......	......	......	......	......	......	......	......	......
Wabash Railroad	......	......	......	......	......	......	......	......	......	......	......
Totals	14.89	49.36	49.42	49.42	54.20	58.08	64.00	67.90	69.73	70.53	72.52

* Includes Pennsylvania R. R. branches.

TABLE CXCIV. TRACK MILEAGE OF STEAM RAILROADS (SIDINGS) IN ZONE B IN INDIANA

Railroad	Sidings — Miles										
	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.	......	......	......	......	......	......	......	......	......	......	......
Baltimore & Ohio R. R.	0.91	24.82	24.68	21.38	21.62	21.65	21.65	21.67	21.67	21.67	21.67
Baltimore & Ohio Chicago Terminal R. R.	5.10	18.68	18.68	20.72	21.08	21.43	21.43	21.43	21.49	21.61	21.89
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	0.08	0.08	2.87	2.62	3.62	3.62
Chicago & Alton R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Eastern Illinois R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Erie R. R.	12.11	20.38	20.38	21.10	27.02	27.02	27.53	25.69	25.69	25.69	28.20
Chicago & Illinois Western R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & North Western Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	......	......	......	......	......	......	......	......	......	......	......
Chicago, Burlington & Quincy R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago Great Western R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Indiana & Southern R. R.	......	6.74	6.52	10.26	14.39	67.89	73.19	80.03	80.61	85.69	93.20
Chicago, Indianapolis & Louisville Ry.	2.60	3.72	12.08	17.66	17.93	18.23	18.23	19.22	20.26	20.34	20.34
Chicago Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Milwaukee & St. Paul Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Rock Island & Pacific Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Short Line Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago, West Pullman & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Elgin, Joliet & Eastern Ry.	0.46	14.33	17.96	19.54	27.26	32.09	33.31	49.36	58.32	91.81	113.63
Grand Trunk Western Ry.	......	......	......	......	......	......	......	......	......	......	......
Illinois Central R. R.	......	......	......	......	......	......	......	......	......	......	......
Illinois Northern Ry.	......	......	......	......	......	......	......	......	......	......	......
Indiana Harbor Belt R. R.	......	9.32	9.32	9.60	9.60	9.55	11.55	11.55	12.76	14.07	19.64
Lake Shore & Michigan Southern Ry.	3.69	11.22	11.72	12.43	13.51	26.63	26.52	29.58	31.23	33.74	35.73
Manufacturers' Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Michigan Central R. R.	3.47	2.79	2.79	3.53	3.16	3.27	4.34	6.59	6.14	6.14	6.19
Minneapolis, St. Paul & Sault Ste. Marie Ry.	......	......	......	......	......	......	......	......	......	......	......
New York, Chicago & St. Louis R. R.	1.25	1.62	1.67	1.54	1.48	2.99	2.42	2.55	3.08	3.55	3.55
Pere Marquette R. R.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Fort Wayne & Chicago Ry.*	3.79	15.15	15.75	17.80	18.69	19.74	26.16	23.65	28.87	31.62	31.93
Pullman Railroad	......	......	......	......	......	......	......	......	......	......	......
Wabash Railroad	......	1.44	1.44	1.44	1.44	1.44	1.40	1.40	1.40	1.40	1 40
Totals	33.38	130.21	142 99	157.00	177.18	252.01	267 81	295 59	314 14	360 95	400.99

TABLE CXCV. TRACK MILEAGE OF STEAM RAILROADS (MAIN TRACK AND SIDINGS) IN ZONE B IN INDIANA

Railroad	Main Track and Sidings — Miles										
	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.	......	......	......	......	......	......	......	......	......	......	......
Baltimore & Ohio R. R.	23.33	47.24	47.10	43.74	43.98	44.01	44.01	44.03	44.03	44.03	44.03
Baltimore & Ohio Chicago Terminal R. R.	12.10	30.77	31.39	31.06	31.46	32.00	32.00	31.63	31.77	31.89	32.17
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	2.72	2.72	5.51	5.26	6.24	5.08
Chicago & Alton R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Eastern Illinois R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Erie R. R.	16.39	24.66	24.66	25.38	33.53	33.56	34.07	32.23	32.23	32.76	35.37
Chicago & Illinois Western R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & North Western Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	......	......	......	......	......	......	......	......	......	......	......
Chicago, Burlington & Quincy R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago Great Western R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Indiana & Southern R. R.	......	16.34	16.24	19.96	22.40	85.19	89.91	99.17	99.75	104.65	112.60
Chicago, Indianapolis & Louisville Ry.	6.66	7.78	16.14	21.72	21.99	22.29	22.29	23 28	24.32	24.40	24.40
Chicago Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Milwaukee & St. Paul Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Rock Island & Pacific Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Short Line Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago, West Pullman & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Elgin, Joliet & Eastern Ry.	1 72	41.51	45.14	46.66	54.29	59.12	60.34	80.90	90.67	124.22	147.37
Grand Trunk Western Ry.	......	......	......	......	......	......	......	......	......	......	......
Illinois Central R. R.	......	......	......	......	......	......	......	......	......	......	......
Illinois Northern Ry.	......	......	......	......	......	......	......	......	......	......	......
Indiana Harbor Belt R. R.	......	18.53	18.53	18.57	18.57	18.52	20.79	20.79	22.00	23 31	28 77
Lake Shore & Michigan Southern Ry.	15 00	33.84	34.34	35.05	46.37	59.49	59.36	62.43	70.12	72 63	75.47
Manufacturers' Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Michigan Central R. R.	10.83	9.47	9.47	10.21	9.84	13.45	18.24	21.66	21.22	21 22	21.27
Minneapolis, St. Paul & Sault Ste. Marie Ry.	......	......	......	......	......	......	......	......	......	......	......
New York, Chicago & St. Louis R. R.	6.35	6.72	6 77	6.64	6.58	8.09	12 16	12 34	12 87	13.34	13 39
Pere Marquette R. R.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Fort Wayne & Chicago Ry.*	18.16	44.73	45.39	47.44	48.33	50.14	56.56	53.76	58.96	61 70	62 02
Pullman Railroad	......	......	......	......	......	......	......	......	......	......	......
Wabash Railroad	......	4.75	4.75	4.75	4.75	4.75	4.71	4 71	4 71	4 71	4 71
Totals	110.54	286.34	299.92	311.18	342.09	433 33	457.16	492.44	517 91	565 10	606 65

* Includes Pennsylvania R. R. branches.

TABLE CXCVI. TRACK MILEAGE OF STEAM RAILROADS (FIRST MAIN TRACK) IN ZONE B IN ILLINOIS AND INDIANA*

Railroad	First Main Track — Miles										
	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.†	8.36	6.32	6.32	6.32	6.32	6.32	6.32	6.32	6.31	6.31	6.31
Baltimore & Ohio R. R.	17.12	11.21	11.21	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18
Baltimore & Ohio Chicago Terminal R. R.	16.10	52.45	52.00	49.63	49.67	49.66	49.66	49.29	49.29	46.63	45.66
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	2.64	2.64	2.64	2.64	2.62	1.46
Chicago & Alton R. R.	6.62	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Eastern Illinois R. R.	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54
Chicago & Erie R. R.	4.28	4.28	4.28	4.28	4.25	4.28	4.28	4.28	4.28	4.25	4.28
Chicago & Illinois Western R. R.	......	......	......	......	6.91	8.14	8.14	8.14	8.14	8.14	8.14
Chicago & North Western Ry.	29.32	15.70	18.59	18.59	18.59	18.59	18.65	18.65	18.65	18.53	18.53
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	40.21	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11
Chicago, Burlington & Quincy R. R.	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33
Chicago Great Western R. R.	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98
Chicago, Indiana & Southern R. R.	......	4.82	4.88	4.86	4.51	11.86	11.28	13.70	13.70	13.52	13.83
Chicago, Indianapolis & Louisville Ry.	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06
Chicago Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Milwaukee & St. Paul Ry.	34.51	12.15	12.15	12.15	12.15	12.15	12.15	12.15	12.16	12.16	12.16
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Rock Island & Pacific Ry.	19.52	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73
Chicago Short Line Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Ry.	......	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.84
Chicago, West Pullman & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Elgin, Joliet & Eastern Ry.	1.26	19.47	19.47	19.38	19.29	19.29	19.29	21.13	21.31	21.13	21.15
Grand Trunk Western Ry.	21.42	12.82	12.82	12.82	12.82	12.83	12.83	12.83	12.85	12.85	12.85
Illinois Central R. R.‡	27.86	14.05	14.14	14.14	14.14	14.14	14.14	14.14	14.14	14.14	14.14
Illinois Northern Ry.†	......	......	......	......	......	......	......	......	......	......	......
Indiana Harbor Belt R. R.	......	35.13	35.13	35.17	35.17	35.17	35.10	35.10	35.10	35.10	36.64
Lake Shore & Michigan Southern Ry.	18.92	11.31	11.31	11.31	17.69	17.69	17.69	17.69	22.62	22.62	23.01
Manufacturers' Junction Ry.	......	......	......	0.86	0.94	1.76	1.76	1.76	1.76	1.76	1.76
Michigan Central R. R.	9.98	6.44	6.41	6.41	6.41	8.16	10.61	10.61	10.88	10.88	10.81
Minneapolis, St. Paul & Sault Ste. Marie Ry.	6.64	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.25	7.25
New York, Chicago & St. Louis R. R.	15.07	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38
Pere Marquette R. R.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	21.90	9.22	9.22	9.22	9.22	9.22	9.22	9.22	9.22	9.22	9.22
Pittsburgh, Fort Wayne & Chicago Ry.¶	39.64	23.28	23.34	23.34	23.34	24.10	24.07	23.79	23.77	23.76	23.77
Pullman Railroad	......	......	......	......	......	......	......	......	......	......	......
Wabash Railroad	9.94	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46
Totals	369.58	297.70	300.32	298.71	311.65	326.23	328.06	331.67	337.05	333.75	334.16

TABLE CXCVII. TRACK MILEAGE OF STEAM RAILROADS (SECOND MAIN TRACK) IN ZONE B IN ILLINOIS AND INDIANA*

Railroad	Second Main Track— Miles										
	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.†	......	......	......	0.32	6.32	6.32	6.32	6.32	6.31	6.31	6.31
Baltimore & Ohio R. R.	17.08	11.21	11.21	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18
Baltimore & Ohio Chicago Terminal R. R.	7.30	18.30	21.91	23.88	23.90	24.98	28.75	27.33	27.41	27.41	25.55
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	......	......	......	......	......	......
Chicago & Alton R. R.	6.62	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Eastern Illinois R. R.	3.54	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55
Chicago & Erie R. R.	......	......	......	......	2.26	2.26	2.26	2.26	2.26	2.82	2.89
Chicago & Illinois Western R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & North Western Ry.	29.32	15.71	18.58	18.58	18.58	18.58	18.65	18.65	18.65	18.54	39.61
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	27.92	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11
Chicago, Burlington & Quincy R. R.	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	16.67
Chicago Great Western R. R.	......	......	......	......	......	......	......	0.06	0.82	4.98	4.98
Chicago, Indiana & Southern R. R.	......	4.78	4.84	4.84	3.50	5.44	5.44	5.44	5.44	5.44	5.57
Chicago, Indianapolis & Louisville Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Milwaukee & St. Paul Ry.	17.92	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.67	11.67	11.68
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Rock Island & Pacific Ry.	13.52	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73
Chicago Short Line Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Ry.	......	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.86
Chicago, West Pullman & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Elgin, Joliet & Eastern Ry.	......	7.71	7.71	7.74	7.74	7.74	7.74	10.41	11.04	11.28	12.59
Grand Trunk Western Ry.	3.82	12.82	12.82	12.82	12.81	12.84	12.82	12.82	12.82	12.82	12.82
Illinois Central R. R.‡	20.21	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	7.69
Illinois Northern Ry.†	......	......	......	......	......	......	......	......	......	......	......
Indiana Harbor Belt R. R.	......	19.80	20.03	20.30	20.30	24.90	23.33	23.33	23.33	23.33	23.84
Lake Shore & Michigan Southern Ry.	7.33	11.31	11.31	11.31	15.17	15.17	15.15	15.16	16.27	16.27	16.70
Manufacturers' Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Michigan Central R. R.	3.68	6.44	6.40	6.40	6.40	8.15	12.00	10.59	10.87	10.87	10.79
Minneapolis, St. Paul & Sault Ste. Marie Ry.	......	0.95	3.38	5.40	7.36	7.36	7.36	7.36	7.36	7.25	7.25
New York, Chicago & St. Louis R. R.	2.32	......	......	......	......	......	5.92	5.97	5.97	5.97	6.02
Pere Marquette R. R.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	4.55	9.22	9.22	9.22	9.22	9.22	9.22	9.22	9.22	9.22	9.22
Pittsburgh, Fort Wayne & Chicago Ry.¶	10.61	11.01	11.01	11.01	11.01	11.01	11.04	11.04	11.04	11.04	11.04
Pullman Railroad	......	......	......	......	......	......	......	......	......	......	......
Wabash Railroad	......	......	......	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15
Totals	184.07	174.07	183.14	191.87	204.65	214.02	226.05	226.01	228.88	233.62	267.35

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* In 1889, "Zone B in Illinois" refers to the territory between the boundary line of the Area of Investigation and the city limits of Chicago as existing May 1, 1889. For all other years the two Zones were the same as at the end of the Committee's statistical year, 1912. Morgan Park is included in Zone B.

† Decrease or increase due to change in classification.

‡ Includes charter line which pays no taxes to Cook County.

¶ Includes Pennsylvania R. R. branches.

TABLE CXCVIII. TRACK MILEAGE OF STEAM RAILROADS (SIDINGS) IN ZONE B IN ILLINOIS AND INDIANA*

Railroad	Sidings — Miles										
	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.†	17.25	1.92	1.90	1.94	2.21	2.67	2.52	2.52	2.57	2.56	2.04
Baltimore & Ohio R. R.	18.44	24.82	24.68	21.38	21.62	21.65	21.65	21.67	21.67	21.67	21.67
Baltimore & Ohio Chicago Terminal R. R.	16.42	41.67	41.45	51.12	54.44	55.56	54.51	54.93	53.16	55.63	59.64
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	0.08	0.08	2.87	2.62	3.62	3.62
Chicago & Alton R. R.	0.25	0.21	1.46	1.47	1.48	1.48	1.48	1.45	1.48	13.43	19.31
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Eastern Illinois R. R.	16.08	31.07	31.51	31.58	60.31	60.58	62.00	62.36	62.36	62.36	62.51
Chicago & Erie R. R.	12.11	20.38	20.38	21.10	27.02	27.02	27.53	25.69	25.69	25.69	28.20
Chicago & Illinois Western R. R.	......	......	......	......	1.68	2.09	2.40	2.31	2.31	2.31	2.31
Chicago & North Western Ry.	10.23	11.58	14.72	22.17	51.71	52.40	41.43	42.09	45.70	60.56	76.84
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	58.91	10.01	10.01	9.85	11.97	11.97	11.97	11.97	11.97	11.97	12.91
Chicago, Burlington & Quincy R. R.	25.98	55.18	55.80	53.14	53.35	61.95	62.24	62.25	64.73	65.50	59.96
Chicago Great Western R. R.	0.91	1.92	2.06	1.97	1.97	1.97	2.14	4.02	4.27	5.28	5.28
Chicago, Indiana & Southern R. R.	......	6.74	6.52	10.26	14.39	67.89	73.19	80.03	80.61	85.69	93.20
Chicago, Indianapolis & Louisville Ry.	2.60	3.72	12.08	17.66	17.93	18.23	18.23	19.22	20.26	20.34	20.34
Chicago Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Milwaukee & St. Paul Ry.	14.92	8.70	8.31	10.00	9.89	10.27	11.21	12.23	8.73	50.62	51.59
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Rock Island & Pacific Ry.	45.49	41.45	41.65	41.95	41.95	41.94	41.95	41.93	41.93	42.92	42.92
Chicago Short Line Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Ry.	......	84.82	84.82	84.82	84.82	84.82	84.82	84.82	84.82	84.82	84.51
Chicago, West Pullman & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Elgin, Joliet & Eastern Ry.	0.46	21.99	25.62	27.20	35.08	39.81	41.03	57.08	65.98	99.47	121.31
Grand Trunk Western Ry.	23.77	7.87	7.87	7.87	7.87	7.87	7.87	7.85	7.85	7.74	8.15
Illinois Central R. R.‡	10.48	11.93	18.49	18.49	18.60	18.60	18.68	18.77	19.31	19.31	18.83
Illinois Northern Ry.†	......	......	......	......	......	......	......	......	......	......	......
Indiana Harbor Belt R. R.	......	33.10	33.48	34.07	33.68	36.70	35.37	35.38	37.02	39.06	67.23
Lake Shore & Michigan Southern Ry.	37.20	11.22	11.72	12.43	13.51	26.63	26.52	29.58	31.23	33.74	35.73
Manufacturers' Junction Ry.	......	......	......	0.28	1.32	3.93	4.00	4.00	4.00	3.58	3.59
Michigan Central R. R.	12.49	7.34	7.32	8.08	7.69	7.80	9.11	14.85	11.84	11.84	11.76
Minneapolis, St. Paul & Sault Ste. Marie Ry.	1.39	9.54	9.89	9.91	10.47	10.47	10.41	10.47	11.92	16.95	17.30
New York, Chicago & St. Louis R. R.	14.36	3.08	3.13	3.00	2.94	5.56	4.59	4.76	5.21	5.68	5.72
Pere Marquette R. R.	......	......	......	......	......	......	......	......	2.17	8.62	8.62
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	7.71	3.67	3.37	4.01	3.90	4.03	3.96	4.92	4.70	4.86	4.92
Pittsburgh, Fort Wayne & Chicago Ry.¶	29.73	17.84	18.44	20.60	21.49	22.67	28.88	26.43	31.53	34.42	34.67
Pullman Railroad	......	......	......	......	......	......	......	......	......	......	......
Wabash Railroad	6.36	3.22	3.17	3.67	3.67	3.67	3.63	3.63	3.63	3.63	3.54
Totals	383.54	474.99	499.85	530.02	616.96	710.31	713.40	750.08	771.27	903.87	988.22

TABLE CXCIX. TRACK MILEAGE OF STEAM RAILROADS (MAIN TRACK AND SIDINGS) IN ZONE B IN ILLINOIS AND INDIANA*

Railroad	Main Track and Sidings — Miles										
	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.†	25.61	8.24	8.22	8.58	14.85	15.31	15.16	15.16	15.19	15.18	14.66
Baltimore & Ohio R. R.	52.64	47.24	47.10	43.74	43.98	44.01	44.01	44.03	44.03	44.03	44.03
Baltimore & Ohio Chicago Terminal R. R.	39.82	112.51	115.36	124.63	128.01	130.20	132.92	131.55	129.86	129.67	130.85
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	2.72	2.72	5.51	5.26	6.24	5.08
Chicago & Alton R. R.	13.49	11.31	12.56	12.57	12.58	12.58	12.58	12.55	12.58	24.53	30.41
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Eastern Illinois R. R.	23.16	38.16	38.60	38.67	67.40	67.67	69.09	69.45	69.45	69.45	69.60
Chicago & Erie R. R.	16.39	24.66	24.66	25.38	33.53	33.56	34.07	32.23	32.23	32.76	35.37
Chicago & Illinois Western R. R.	......	......	......	......	8.59	10.23	10.54	10.45	10.45	10.45	10.45
Chicago & North Western Ry.	68.87	42.99	51.89	59.34	88.88	89.57	78.73	79.39	83.00	97.63	134.98
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	127.04	16.23	16.23	16.07	18.19	18.19	18.19	18.19	18.19	18.19	19.13
Chicago, Burlington & Quincy R. R.	42.64	71.84	72.46	69.80	70.01	78.61	78.90	78.91	81.39	82.16	84.96
Chicago Great Western R. R.	5.89	6.90	7.04	6.95	6.95	6.95	7.12	9.06	10.07	15.24	15.24
Chicago, Indiana & Southern R. R.	......	16.34	16.24	19.96	22.40	85.19	89.91	99.17	99.75	104.65	112.60
Chicago, Indianapolis & Louisville Ry.	6.66	7.78	16.14	21.72	21.99	22.29	22.29	23.28	24.32	24.40	24.40
Chicago Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Milwaukee & St. Paul Ry.	67.35	32.50	32.11	33.80	33.69	34.07	35.01	36.03	32.56	74.45	75.43
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago, Rock Island & Pacific Ry.	78.53	50.91	51.11	51.41	51.41	51.40	51.41	51.39	51.39	52.38	52.38
Chicago Short Line Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Ry.	......	92.20	92.20	92.20	92.20	92.20	92.20	92.20	92.20	92.20	92.21
Chicago, West Pullman & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Elgin, Joliet & Eastern Ry.	1.72	49.17	52.80	54.32	62.11	66.84	68.06	88.62	98.33	131.88	155.05
Grand Trunk Western Ry.	49.01	33.51	33.51	33.51	33.53	33.54	33.52	33.50	33.52	33.41	33.82
Illinois Central R. R.‡	58.55	29.96	36.61	36.61	36.72	36.72	36.80	36.89	37.43	37.43	40.66
Illinois Northern Ry.†	......	......	......	......	......	......	......	......	......	......	......
Indiana Harbor Belt R. R.	......	88.03	88.64	89.54	89.15	96.77	93.80	93.81	95.45	97.49	127.71
Lake Shore & Michigan Southern Ry.	63.45	33.84	34.34	35.05	46.37	59.49	59.36	62.43	70.12	72.63	75.47
Manufacturers' Junction Ry.	......	......	......	1.14	2.26	5.69	5.76	5.76	5.76	5.34	5.35
Michigan Central R. R.	26.15	20.22	20.13	20.89	20.50	24.11	31.72	36.05	33.59	33.59	33.36
Minneapolis, St. Paul & Sault Ste. Marie Ry.	8.03	17.84	20.62	22.66	25.18	25.18	25.12	25.18	26.63	31.45	31.80
New York, Chicago & St. Louis R. R.	31.75	9.46	9.51	9.38	9.32	11.94	16.89	17.11	17.56	18.03	18.12
Pere Marquette R. R.	......	......	......	......	......	......	......	......	2.17	8.62	8.62
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	34.16	22.11	21.81	22.45	22.34	22.47	22.40	23.36	23.14	23.30	23.36
Pittsburgh, Fort Wayne & Chicago Ry.¶	79.98	52.13	52.79	54.95	55.84	57.78	63.99	61.26	66.34	69.22	69.48
Pullman Railroad	......	......	......	......	......	......	......	......	......	......	......
Wabash Railroad	16.30	10.68	10.63	15.28	15.28	15.28	15.24	15.24	15.24	15.24	15.15
Totals	937.19	946.76	983.31	1,020.60	1,133.26	1,250.56	1,267.51	1,307.76	1,337.20	1,471.24	1,589.73

* In 1889, "Zone B in Illinois" refers to the territory between the boundary line of the Area of Investigation and the city limits of Chicago as existing May 1, 1889. For all other years the two Zones were the same as at the end of the Committee's statistical year, 1912. Morgan Park is included in Zone B.

† Decrease or increase due to change in classification.

‡ Includes charter line which pays no taxes to Cook County

¶ Includes Pennsylvania R. R. branches.

TABLE CC. TRACK MILEAGE OF STEAM RAILROADS (FIRST MAIN TRACK) IN ZONES A AND B IN ILLINOIS AND INDIANA

Railroad	First Main Track—Miles										
	1889**	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.*	10.10	13.69	13.69	13.69	13.69	13.69	13.69	13.69	13.71	13.71	12.32
Baltimore & Ohio R. R.	17.12	19.30	19.30	19.27	19.27	19.27	19.27	19.27	19.27	19.27	19.27
Baltimore & Ohio Chicago Terminal R. R.	24.89	70.34	69.70	67.40	67.44	67.43	67.43	67.06	67.06	64.40	63.38
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	......	1.21
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	2.64	2.64	2.64	2.64	2.62	1.46
Chicago & Alton R. R.	12.68	12.67	12.67	12.67	12.67	12.67	12.67	12.67	12.67	12.67	12.67
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	1.68	1.68	1.68
Chicago & Eastern Illinois R. R.	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54
Chicago & Erie R. R.	4.28	4.28	4.28	4.28	4.25	4.28	4.28	4.28	4.28	4.25	4.28
Chicago & Illinois Western R. R.	......	......	......	......	6.94	8.17	8.17	10.30	10.30	10.30	10.30
Chicago & North Western Ry.	42.05	49.74	53.85	53.85	53.85	51.03	54.09	54.09	54.09	51.09	54.09
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	47.89	47.36	47.36	47.36	47.36	47.36	47.36	47.36	47.36	47.36	47.36
Chicago, Burlington & Quincy R. R.†	13.80	13.80	13.80	13.80	13.80	13.98	13.98	13.98	13.98	13.98	13.98
Chicago Great Western R. R.	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98
Chicago, Indiana & Southern R. R.	......	4.82	4.88	4.86	4.51	11.86	11.28	13.70	13.70	13.52	13.83
Chicago, Indianapolis & Louisville Ry.	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06
Chicago Junction Ry.	......	11.91	11.91	11.91	11.91	11.91	11.91	11.57	11.57	11.65	11.31
Chicago, Milwaukee & St. Paul Ry.	42.28	41.00	41.00	41.00	41.00	41.00	41.00	41.02	41.03	41.03	41.03
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	2.24
Chicago, Rock Island & Pacific Ry.	23.18	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15
Chicago Short Line Ry.	......	......	......	......	......	......	0.91	0.91	0.91	0.91	0.91
Chicago Union Transfer Ry.	......	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.28
Chicago, West Pullman & Southern R. R.	......	......	......	......	......	......	......	1.17	1.17	1.17	1.17
Elgin, Joliet & Eastern Ry.	1.26	21.23	21.23	21.14	21.05	21.05	21.05	22.89	23.02	22.84	23.88
Grand Trunk Western Ry.	21.42	21.34	21.34	21.34	21.34	21.35	21.35	21.35	21.37	21.37	21.37
Illinois Central R. R.‡	32.92	44.44	44.19	44.19	44.19	43.78	43.78	43.78	43.78	43.78	43.82
Illinois Northern Ry.*	......	......	19.79	12.25	12.25	12.15	4.51	4.11	4.11	4.11	4.11
Indiana Harbor Belt R. R.	......	40.35	40.35	40.39	40.39	40.39	40.44	40.44	40.44	40.44	41.92
Lake Shore & Michigan Southern Ry.	18.92	18.92	18.92	18.92	25.30	25.30	25.30	25.30	30.23	30.23	30.65
Manufacturers' Junction Ry.	......	......	......	0.86	0.94	1.76	1.76	1.76	1.76	1.76	1.76
Michigan Central R. R.	9.98	10.23	10.20	10.20	10.20	11.95	14.58	14.99	14.59	14.59	14.58
Minneapolis, St. Paul & Sault Ste. Marie Ry.	6.64	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.25	7.25
New York, Chicago & St. Louis R. R.	15.07	15.07	15.07	15.07	15.07	15.07	15.07	15.06	14.37	14.37	14.37
Pere Marquette R. R.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.¶	29.08	29.14	29.14	29.14	29.14	29.14	29.11	29.13	29.16	29.18	29.18
Pittsburgh, Fort Wayne & Chicago Ry.§	42.94	50.54	50.60	50.60	50.60	51.36	51.35	51.06	51.07	51.06	51.40
Pullman Railroad	......	......	......	......	......	......	......	......	......	2.71	2.71
Wabash Railroad	9.94	12.38	12.38	12.38	12.38	12.38	12.38	12.38	12.38	12.38	12.38
Totals	439.02	602.63	625.73	616.65	629.62	644.05	639.44	646.07	651.78	651.41	654.95

TABLE CCI. TRACK MILEAGE OF STEAM RAILROADS (SECOND MAIN TRACK) IN ZONES A AND B IN ILLINOIS AND INDIANA

Railroad	Second Main Track—Miles										
	1889**	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.*	......	5.75	5.75	6.07	12.23	12.23	12.23	12.23	12.25	12.25	12.24
Baltimore & Ohio R. R.	17.08	19.26	19.26	19.23	19.23	19.23	19.23	19.23	19.23	19.23	19.23
Baltimore & Ohio Chicago Terminal R. R.	14.74	34.58	38.10	40.07	40.09	41.17	46.46	45.05	45.13	45.13	43.25
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	......	......
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	......	......	......	......	......	......
Chicago & Alton R. R.	12.21	5.55	5.55	5.55	12.67	12.67	12.67	12.67	12.67	12.67	12.67
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & Eastern Illinois R. R.	3.54	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55
Chicago & Erie R. R.	......	......	......	......	2.26	2.26	2.26	2.26	2.26	2.82	2.80
Chicago & Illinois Western R. R.	......	......	......	......	......	......	......	......	......	......	......
Chicago & North Western Ry.	41.29	49.01	53.09	53.09	53.09	53.26	53.33	53.33	53.33	53.14	102.39
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	31.11	41.41	41.41	41.41	41.41	41.41	41.41	41.41	41.41	41.41	41.41
Chicago, Burlington & Quincy R. R.†	13.80	13.80	13.80	13.80	13.80	13.98	13.98	13.98	13.98	13.98	32.77
Chicago Great Western R. R.	......	......	......	......	......	......	......	0.06	0.82	4.98	4.98
Chicago, Indiana & Southern R. R.	......	4.78	4.84	4.84	3.50	5.44	5.44	5.44	5.44	5.44	5.57
Chicago, Indianapolis & Louisville Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Junction Ry.	......	11.20	11.20	11.20	11.20	11.20	11.20	9.69	10.86	10.86	10.86
Chicago, Milwaukee & St. Paul Ry.	25.13	37.54	37.54	37.54	37.54	37.54	37.54	37.56	37.58	37.58	37.59
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	0.81
Chicago, Rock Island & Pacific Ry.	17.18	22.44	22.44	22.44	22.44	22.44	22.44	22.44	22.44	22.44	22.44
Chicago Short Line Ry.	......	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Ry.	......	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.05
Chicago, West Pullman & Southern R. R.	......	......	......	......	......	......	......	......	......	......	......
Elgin, Joliet & Eastern Ry.	......	9.47	9.47	9.50	9.50	9.50	9.50	12.17	12.75	12.90	15.29
Grand Trunk Western Ry.	3.82	21.34	21.34	21.34	21.36	21.36	21.34	21.34	21.34	21.34	21.34
Illinois Central R. R.‡	24.85	30.95	30.99	30.99	30.99	30.99	30.99	30.99	30.99	30.99	34.91
Illinois Northern Ry.*	......	......	......	......	......	......	......	......	......	......	......
Indiana Harbor Belt R. R.	......	24.83	25.06	25.33	25.33	29.93	28.67	28.67	28.67	28.67	29.12
Lake Shore & Michigan Southern Ry.	7.33	18.92	18.92	18.92	22.78	22.78	22.76	22.77	23.88	23.88	24.31
Manufacturers' Junction Ry.	......	......	......	......	......	......	......	......	......	......	......
Michigan Central R. R.	5.09	10.22	10.15	10.18	10.18	11.93	15.96	14.94	14.58	14.58	14.57
Minneapolis, St. Paul & Sault Ste. Marie Ry.	......	0.95	3.38	5.40	7.36	7.36	7.36	7.26	7.36	7.25	7.25
New York, Chicago & St. Louis R. R.	2.32	......	......	......	......	......	14.57	14.62	14.00	14.00	14.01
Pere Marquette R. R.	......	......	......	......	......	......	......	......	......	......	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.¶	11.73	26.79	26.79	26.79	26.79	26.79	26.79	26.80	26.83	26.84	26.84
Pittsburgh, Fort Wayne & Chicago Ry.§	13.55	28.00	28.00	28.00	28.00	28.00	28.03	28.00	28.01	28.01	28.01
Pullman Railroad	......	......	......	......	......	......	......	......	......	1.24	1.25
Wabash Railroad	......	......	......	9.08	9.08	9.08	9.07	9.08	9.07	9.07	9.07
Totals	244.77	424.35	434.64	448.33	468.39	478.11	500.79	499.65	502.44	508.35	582.68

* Decrease or increase due to change in classification.

† Increase due to St. Charles Air Line.

‡ Includes charter line which pays no taxes to Cook County.

¶ Includes Englewood Connecting Ry.

§ Includes all Pennsylvania R. R. branches except Englewood Connecting Ry.

** Figures for 1889 include only the territory within the Chicago city limits May 1, 1889. Morgan Park is not included in Zone A.

TABLE CCII. TRACK MILEAGE OF STEAM RAILROADS (SIDINGS) IN ZONES A AND B IN ILLINOIS AND INDIANA

Railroad	Sidings—Miles										
	1889**	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.*	27.94	44.56	40.51	40.73	42.71	46.49	45.69	48.88	49.76	54.76	58.57
Baltimore & Ohio R. R.	20.81	49.78	49.64	46.34	46.58	47.32	47.32	47.40	47.89	47.89	47.89
Baltimore & Ohio Chicago Terminal R. R.	29 00	88.83	89.06	100.47	104.83	106.32	104.99	105.58	102.98	106.20	110.24
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	7.14	5.93
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	0.08	0.08	2.87	2.62	3.62	3.62
Chicago & Alton R. R.	21.64	38.04	33.29	33.30	34.08	34.08	34.11	34.39	34 51	47.65	55.83
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	1.29	1 29	1.29
Chicago & Eastern Illinois R. R.	16.90	43.34	38.27	38.36	67.23	67.53	68.90	69.26	69.26	69.27	69.43
Chicago & Erie R. R.	12.11	20.38	20.38	21.10	27.02	27.02	27.53	25.69	25.69	25.69	28.20
Chicago & Illinois Western R. R.	......	......	......	......	1.68	2.09	2.40	2.31	2.31	2 31	2.31
Chicago & North Western Ry.	118.74	183.77	189.04	234.68	270.98	279.04	266.57	270.41	277.12	388.14	332.07
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	82.50	125.75	145.31	145.15	156.03	178.03	178.04	179.04	180.03	194.56	211.11
Chicago, Burlington & Quincy R. R.†	92.65	131.58	134.18	137.14	137.35	142.12	147.21	148.86	167.58	155.68	144.33
Chicago Great Western R. R.	0.91	7.81	17.97	17.90	18.04	18.04	22.19	24.07	15.32	16.76	16.88
Chicago, Indiana & Southern R. R.	......	6.74	6.52	10.26	14.39	67.89	73.19	80.03	80.61	85.69	93.20
Chicago, Indianapolis & Louisville Ry.	2.60	3.72	12.08	17.66	17.93	18.23	18.23	19.22	20.26	20.34	20.34
Chicago Junction Ry.	......	111.43	119.17	123.73	132.24	133.57	135.98	112.06	116.42	120.12	125.69
Chicago, Milwaukee & St. Paul Ry.	69.83	126.29	125.74	128.95	133.58	136.01	137.95	140.36	153.55	196.47	197.87
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	1.07
Chicago, Rock Island & Pacific Ry.	60.81	116.62	116.82	117.99	117.99	118.93	118.94	118.97	120.52	122.62	122.54
Chicago Short Line Ry.	......	......	......	......	......	......	3.21	3.21	3.21	3.21	3.21
Chicago Union Transfer Ry.	......	87.44	87.44	87.44	87.44	87.44	87.44	87.44	87.44	87.76	87.60
Chicago, West Pullman & Southern R. R.	......	1.54	1.54	1.54	1.54	1.54	0.99	0.89	0.89	0.89	0.89
Elgin, Joliet & Eastern Ry.	0 46	36.93	39.21	42.04	49.92	55.54	56.76	72.81	81.35	114.84	136.61
Grand Trunk Western Ry.	23.77	34.12	34.12	34.12	34.12	34.12	32.81	32.91	32.94	33.08	37.22
Illinois Central R. R.‡	69.90	207.24	243.52	245.05	247.93	251.62	255.71	257.94	259.46	270 65	270.38
Illinois Northern Ry.*	......	......	......	......	......	......	......	2.32	5.75	5.75	5.75
Indiana Harbor Belt R. R.	......	33.10	33 48	34.07	33.68	36.70	37.11	37.12	38.90	41.13	71.06
Lake Shore & Michigan Southern Ry.	49.39	81.56	84.14	85.46	86.49	100.48	101.65	104.20	106.52	109.22	112.30
Manufacturers' Junction Ry.	......	......	......	0.28	1.32	5.09	5.04	4.92	4.92	4.21	4.22
Michigan Central R. R.	12.49	49.70	49.85	50.68	50.29	50.40	52.16	60.46	58.54	58.54	59.37
Minneapolis, St. Paul & Sault Ste. Marie Ry.	1.39	9.54	9.89	9.91	10.47	10.47	10.41	10.47	11.92	16.95	17.30
New York, Chicago & St. Louis R. R.	14.66	27.79	29.91	31.23	32.07	35.11	31.55	31.70	31 20	31.67	32.07
Pere Marquette R. R.	......	......	......	......	......	......	......	......	2.17	8.62	8.62
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.¶	30.44	65.13	68.18	71.16	73.82	78.26	84.27	84.84	85.82	85.96	85.55
Pittsburgh, Fort Wayne & Chicago Ry.§	44.65	96.99	102.76	101.72	116.31	112.63	118.27	117.14	127.63	131.99	134.60
Pullman Railroad	......	......	......	......	......	......	......	......	......	2.58	2.58
Wabash Railroad	6.36	23.12	25.74	26.69	32.35	32.35	32.31	32.31	32.30	32.31	32.21
Totals	809.95	1,852.84	1,947.76	2,035.15	2,180.41	2,314.54	2,339.03	2,369.98	2.438 68	2,705 56	2,749.95

TABLE CCIII. TRACK MILEAGE OF STEAM RAILROADS (MAIN TRACK AND SIDINGS) IN ZONES A AND B IN ILLINOIS AND INDIANA

Railroad	Main Track and Sidings—Miles										
	1889**	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
Atchison, Topeka & Santa Fe Ry.*	38.04	64.00	59.95	60.49	68.63	72.41	71.61	74.80	75.72	80.72	83.13
Baltimore & Ohio R. R.	55.01	88.34	88.20	84.84	85.08	85.82	85.82	85.90	86.39	86.39	86.39
Baltimore & Ohio Chicago Terminal R. R.	68.63	193.75	196.86	207.94	212.36	214.92	218.88	217.69	215.17	215.73	216.87
Calumet, Hammond & Southeastern R. R.	......	......	......	......	......	......	......	......	......	7.14	7.14
Chesapeake & Ohio Ry. of Indiana	......	......	......	......	......	2.72	2.72	5.51	5.26	6.24	5.08
Chicago & Alton R. R.	46.53	56.26	51.51	51.52	59.42	59.42	59.45	59.73	59.85	72.99	81.17
Chicago & Calumet River R. R.	......	......	......	......	......	......	......	......	2.97	2.97	2.97
Chicago & Eastern Illinois R. R.	23.98	50.43	45.36	45.45	74.32	74.62	75.99	76.35	76.35	76.36	76.52
Chicago & Erie R. R.	16.39	24.66	24.66	25.38	33.53	33.56	34.07	32.23	32.23	32.76	35.37
Chicago & Illinois Western R. R.	......	......	......	......	8.62	10.26	10.57	12.61	12.61	12.61	12.61
Chicago & North Western Ry.	202.08	282.52	295.98	341.62	377.92	386.33	373.99	377.83	384.54	495.37	488.55
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	161.50	214.52	234.08	233.92	244.80	266.80	266.81	267.81	268.80	283.33	299.88
Chicago, Burlington & Quincy R. R.†	120.25	159.18	161.78	164.74	164.95	170.08	175.17	176.82	195.54	183.64	191.08
Chicago Great Western R. R.	5.89	12.79	22.95	22.88	23.02	23.02	27.17	29.11	21.12	26.72	26.84
Chicago, Indiana & Southern R. R.	......	16.34	16.24	19.96	22.40	85.19	89.91	99.17	99.75	104.65	112.60
Chicago, Indianapolis & Louisville Ry.	6.66	7.78	16.14	21.72	21.99	22.29	22.29	23.28	24.32	24.40	24.40
Chicago Junction Ry.	......	134.54	142.28	146.84	155.35	156.68	159.09	133.32	138.85	142.63	147.86
Chicago, Milwaukee & St. Paul Ry.	137.24	204.83	204.28	207.49	212.12	214.55	216.49	218.84	232.16	275.08	276.49
Chicago River & Indiana R. R.	......	......	......	......	......	......	......	......	......	......	4.12
Chicago, Rock Island & Pacific Ry.	101.17	162.21	162.41	163.58	163.58	164.52	164.53	164.56	166.11	168.21	168.13
Chicago Short Line Ry.	......	......	......	......	......	......	4.12	4.12	4.12	4.12	4.12
Chicago Union Transfer Ry.	......	98.45	98.45	98.45	98.45	98.45	98.45	98.45	98.45	98.77	98.93
Chicago, West Pullman & Southern R. R.	......	1.54	1.54	1.54	1.54	1.54	0.99	2 06	2.06	2.06	2.06
Elgin, Joliet & Eastern Ry.	1.72	67.63	69.91	72.68	80.47	86.09	87.31	107.87	117.12	150.67	175.78
Grand Trunk Western Ry.	49.01	76.80	76.80	76.80	76.82	76.83	75.50	75.60	75.65	75.79	79.93
Illinois Central R. R.‡	127 67	282.63	318.70	320.23	323.11	326.39	330.48	332.71	334.23	345.42	349.11
Illinois Northern Ry.*	......	......	19.79	12.25	12.25	12.15	4.51	6.43	9.86	9.86	9.86
Indiana Harbor Belt R. R.	......	98.28	98.89	99.79	99.40	107.02	106.22	106.23	108.01	110.24	142.10
Lake Shore & Michigan Southern Ry.	75.64	119.40	121.98	123.30	134.57	148.56	149.71	152.27	160.63	163.33	167.26
Manufacturers' Junction Ry.	......	......	......	1.14	2.26	6.85	6.80	6.68	6.68	5.97	5.98
Michigan Central R. R.	27.56	70.15	70.20	71.06	70.67	74.28	82.70	90.39	87.71	87.71	88.52
Minneapolis, St. Paul & Sault Ste. Marie Ry.	8.03	17.84	20.62	22.66	25.18	25.18	25.12	25.18	26.63	31 45	31.80
New York, Chicago & St. Louis R. R.	32.05	42.86	44.98	46.30	47.14	50.18	61.21	61.38	59.57	60.04	60 45
Pere Marquette R. R.	......	......	......	......	......	......	......	......	2.17	8.62	8 62
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.¶	71.25	121.06	124.11	127.09	129.75	134.19	140.17	140.77	141.81	141.98	141.57
Pittsburgh, Fort Wayne & Chicago Ry.§	101.14	175.53	181.36	180.32	194.91	191.99	197.65	196.23	206.71	211.06	214.07
Pullman Railroad	......	......	......	......	......	......	......	......	......	6.53	6.55
Wabash Railroad	16.30	35.50	38.12	48.15	53.81	53.81	53.76	53 77	53 75	53.76	53.66
Totals	1,493.74	2,879.82	3,008.13	3,100.13	3,278.42	3,436.70	3,479.26	3,515 70	3,592 90	3,865 32	3,987.58

* Decrease or increase due to change in classification.

† Increase due to St. Charles Air Line.

‡ Includes charter line which pays no taxes to Cook County.

¶ Includes Englewood Connecting Ry.

§ Includes all Pennsylvania R. R. branches except Englewood Connecting Ry.

** Figures for 1889 include only the territory within the Chicago city limits May 1, 1889. Morgan Park is not included in Zone A.

TABLE CCIV. TOTAL MILEAGE OF TRACK OF STEAM RAILROADS WITHIN THE AREA OF INVESTIGATION

Location	1889	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
1	2	3	4	5	6	7	8	9	10	11	12
First Main Track											
Zone A, City of Chicago	69.44	304.93	325.41	317.94	317.97	317.82	311.38	314.40	314.73	317.66	320.79
Zone B in Illinois	307.31	190.93	192.81	193.95	200.94	202.99	202.71	202.72	203.01	200.13	201.02
Zone B in Indiana	62.27	106.77	107.51	104.76	110.71	123.24	125.35	128.95	134.04	133.62	133.14
Zone B in Illinois and Indiana	369.58	297.70	300.32	298.71	311.65	326.23	328.06	331.67	337.05	333.75	334.16
Zones A and B	439.02	602.63	625.73	616.65	629.62	644.05	639.44	646.07	651.78	651.41	654.95
Second Main Track											
Zone A, City of Chicago	60.70	250.28	251.50	256.46	263.74	264.09	274.74	273.64	273.56	274.73	315.33
Zone B in Illinois	169.18	124.71	133.72	142.45	150.45	155.94	162.05	158.11	159.15	163.09	194.83
Zone B in Indiana	14.89	49.36	49.42	49.42	54.20	58.08	64.00	67.90	69.73	70.53	72.52
Zone B in Illinois and Indiana	184.07	174.07	183.14	191.87	204.65	214.02	226.05	226.01	228.88	233.62	267.35
Zones A and B	244.77	424.35	434.64	448.33	468.39	478.11	500.79	499.65	502.44	508.35	582.68
Sidings											
Zone A, City of Chicago	426.41	1377.85	1447.91	1505.13	1563.45	1604.23	1625.63	1619.90	1667.41	1801.69	1761.73
Zone B in Illinois	350.16	314.78	356.86	373.02	439.78	458.30	445.59	454.49	457.13	542.92	587.23
Zone B in Indiana	33.38	130.21	142.99	157.00	177.18	252.01	267.81	295.59	314.14	360.95	400.99
Zone B in Illinois and Indiana	383.54	474.99	499.85	530.02	616.96	710.31	713.40	750.08	771.27	903.87	988.22
Zones A and B	809.95	1852.84	1947.76	2035.15	2180.41	2314.54	2339.03	2369.98	2438.68	2705.56	2749.95
Main Track and Sidings											
Zone A, City of Chicago	556.55	1933.06	2024.82	2079.53	2145.16	2186.14	2211.75	2207.94	2255.70	2394.08	2397.85
Zone B in Illinois	826.65	660.42	683.39	709.42	791.17	817.23	810.35	815.32	819.29	906.14	983.08
Zone B in Indiana	110.54	286.34	209.92	311.18	342.09	433.33	457.16	492.44	517.91	565.10	606.65
Zone B in Illinois and Indiana	937.19	946.76	983.31	1020.60	1133.26	1250.56	1267.51	1307.76	1337.20	1471.24	1589.73
Zones A and B	1493.74	2879.82	3008.13	3100.13	3278.42	3436.70	3479.26	3515.70	3592.90	3865.32	3987.58

TABLE CCV. INCREASE IN THE MILEAGE OF RAILROAD TRACK WITHIN THE AREA OF INVESTIGATION

Location	Miles of Main Track and Sidings			Increase					
	1889	1903	1912	1889 to 1903		1903 to 1912		1889 to 1912	
				Miles	Per Cent	Miles	Per Cent	Miles	Per Cent
1	2	3	4	5	6	7	8	9	10
Zone A, City of Chicago	556.55	1933.06	2397.85	1376.51	247.30	464.79	24.05	1841.30	330.80
Zone B in Illinois	826.65	660.42	983.08	*166.23	*20.10	322.66	48.80	156.43	18.91
Zone B in Indiana	110.54	286.34	606.65	175.80	159.00	320.31	111.90	496.11	448.80
Zone B in Illinois and Indiana	937.19	946.76	1589.73	9.57	1.02	642.97	67.90	652.54	69.60
Zones A and B	1493.74	2879.82	3987.58	1386.08	92.80	1107.76	38.50	2493.84	167.10

* Decrease

track per square mile of area), the areas of the zones were assumed to be the same for 1903 as for 1912; hence the percentage of increase in the density of trackage is the same as the percentage of increase in the mileage as shown by table CCV. The same agreement also holds for the Area of Investigation as a whole for all years. The density of railroad trackage, in terms of miles of track per square mile of area, is shown by table CCVI.

203.04 Conclusions with Reference to Rate of Increase of Railroad Trackage: The increase of track mileage within the Area of Investigation, during a period of years, is shown graphically by fig. 431.

TABLE CCVI. INCREASE IN DENSITY OF TRACKAGE WITHIN THE AREA OF INVESTIGATION

Location	Area Square Miles		Average Miles of Main Track and Sidings per Square Mile			Increase in Density of Track Per Square Mile					
						1889 to 1903		1903 to 1912		1889 to 1912	
	1889	1903 to 1912	1889	1903	1912	Miles	Per Cent	Miles	Per Cent	Miles	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12
Zone A, City of Chicago	43.9	191.3	12.65	10.10	12.54	*2.53	*19.95	2.42	24.05	*0.11	*0.87
Zone B in Illinois	342.0	194.6	2.42	3.39	5.04	0.97	40.10	1.65	48.80	2.62	108.25
Zone B in Indiana	42.4	42.4	2.61	6.76	14.30	4.15	159.00	7.54	111.90	11.69	448.80
Zone B in Illinois and Indiana	384.4	237.0	2.44	3.99	6.70	1.55	63.50	2.71	67.90	4.26	174.50
Zones A and B	428.3	428.3	3.48	6.72	9.30	3.24	93.10	2.58	38.50	5.82	167.10

* Decrease.

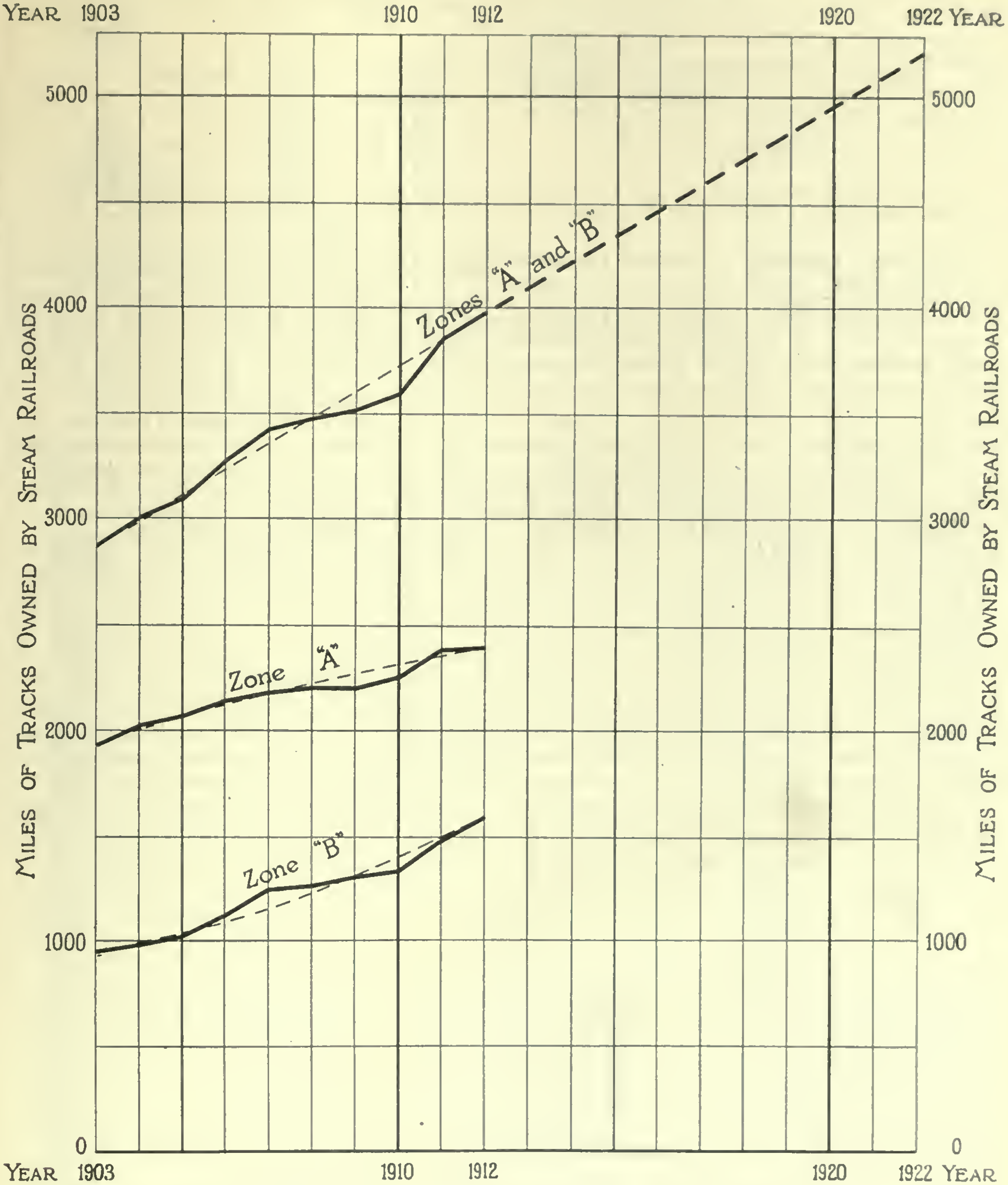


FIG. 431. INCREASE OF TRACK MILEAGE OF THE CHICAGO TERMINALS

In fig. 431, curves relating to the approximate growth are shown superimposed upon the curves of actual growth within Zone A (City of Chicago), within Zone B and within the entire Area of Investigation. By means of points plotted from numerical values, the following equations were obtained:

Zones A and B:

$$T=2880+123\ Y$$

Zone A:

$$T=1933+88.8\ Y^{0.754}$$

Zone B:

$$T=947+34.8\ Y^{1.32}$$

"T" represents the number of miles of track and "Y" the number of years succeeding 1903. For example, the year 1903 is designated as year zero, 1904 as year one, and so on. The first equation shows that the total trackage within the entire Area of Investigation is subject to an annual increment of 123 miles. The growth of trackage in Zone A is a function of the 0.754th power of the number of years succeeding 1903. The mileage in Zone B has increased at a greater rate, the rate being a function of the 1.32th power of the number of years succeeding 1903.

In estimating the probable extent of trackage for any future year, it is assumed that only the total mileage of track within the Area of Investigation need be considered, since it is improbable that the limits of the city will remain unchanged, and since the trackage which will be involved by electrification includes both that lying within the city and that lying within the territory immediately tributary thereto. Predictions of future growth, based upon the assumption that the mileage will continue to increase by increments of about 123 miles per year, are presented in table CCVII.

TABLE CCVII. ESTIMATE OF FUTURE GROWTH OF TRACKAGE WITHIN THE AREA OF INVESTIGATION

Year	Miles of Track	Per Cent of Increase over 1912
1	2	3
1912	3,988	
1913	4,110	3.1
1914	4,235	6.2
1915	4,355	9.2
1916	4,480	12.3
1917	4,605	15.5
1918	4,725	18.5
1919	4,850	21.6
1920	4,970	24.6
1921	5,095	27.7
1922	5,220	30.8

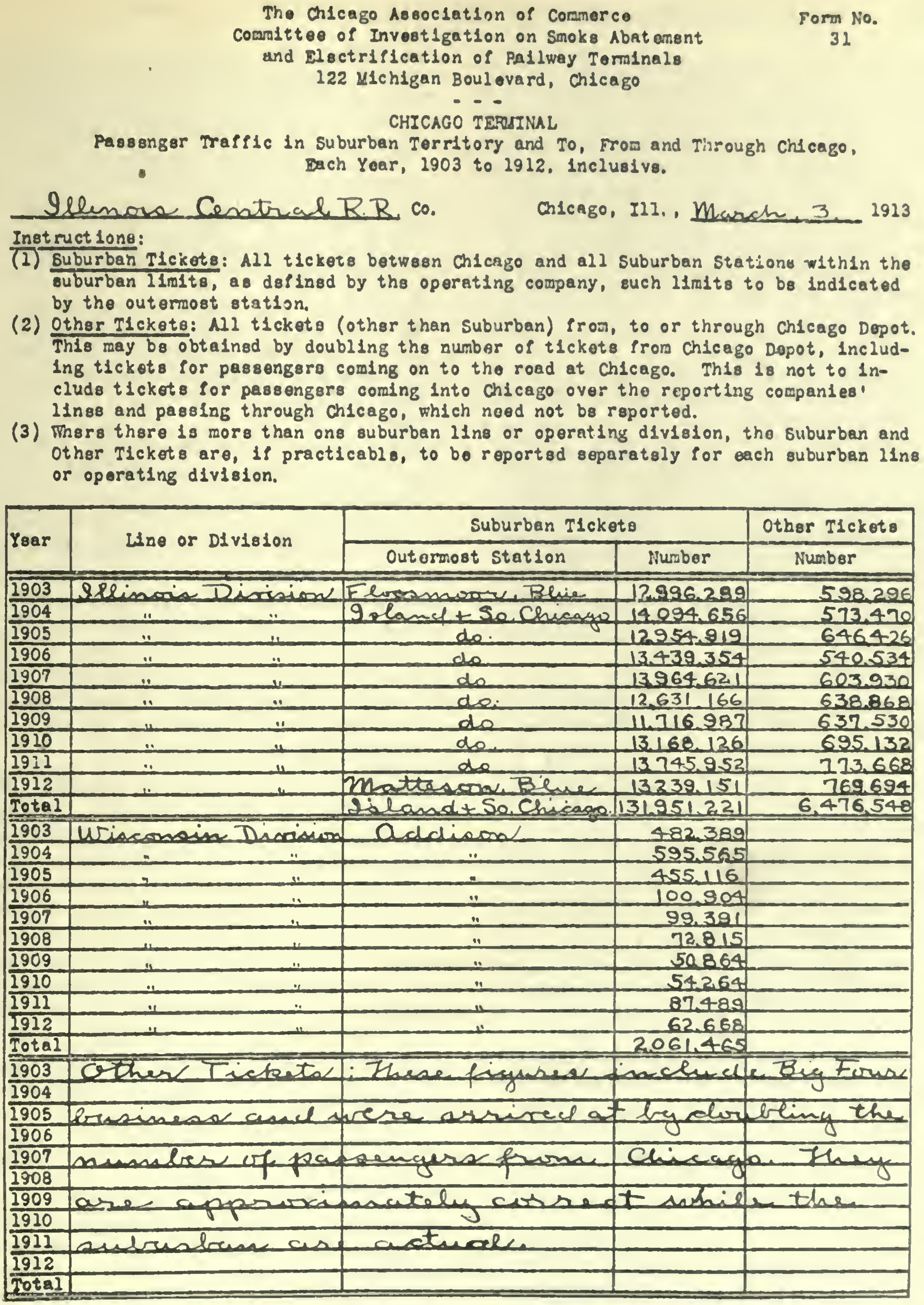
Thus, in 1922 the track mileage owned by railroads will be 30.8 per cent greater than it was in 1912. The average number of miles of track per square mile of territory within the entire Area of Investigation will increase to about 12.2 in 1922, this being somewhat less than the density of trackage within the city in 1912.

203.05 Number of Passengers Carried: Statistics covering the number of passengers carried on all railroads operating within the Area of Investigation were collected by the use of "Form 31," which is reproduced as fig. 432.

The number of tickets, as reported on this form, was assumed to be the same as the number of passengers carried. There were 25 railroads operating passenger service within the Area of Investigation in 1912. Of these, 23 carried through passengers and 17 carried suburban passengers. Through passengers include those carried to or received from points beyond the limits of suburban territory. Suburban passengers are those carried only within the limits of suburban territory, as it is defined by each road. The outermost suburban stations, as reported by the operating roads, are listed in table CCVIII.

TABLE CCVIII. OUTERMOST STATIONS OF SUBURBAN SERVICE OF RAILROADS REPORTING SUBURBAN PASSENGERS

Railroad	Division	Outermost Station	Miles from Chicago Terminus
1	2	3	4
Baltimore & Ohio Chicago Terminal R. R	Chicago Heights Line	Chicago Heights, Ill	30.6
Chesapeake & Ohio Ry. of Indiana	Chesapeake & Ohio Ry of Indiana	Hammond, Ind	20.6
Chicago & Alton R. R	Northern	Joliet, Ill	37.2
Chicago & Eastern Illinois R. R	Chicago Terminal	Crete, Ill	30.4
Chicago & North Western Ry	Galena	West Chicago, Ill	30.0
Chicago & North Western Ry	Wisconsin (Milwaukee)	Waukegan, Ill	35.9
Chicago & North Western Ry	Wisconsin	Barrington, Ill	31.6
Chicago & Western Indiana R. R	Chicago & Dolton	Dolton, Ill	16.6
Chicago, Burlington & Quincy R. R	Chicago & Aurora	Aurora, Ill	37.4
Chicago Great Western R. R	Eastern	St. Charles, Ill	36.0
Chicago, Indiana & Southern R. R	Danville	Gibson, Ind	23.4
Chicago, Milwaukee & St. Paul Ry	Chicago & Milwaukee	Libertyville, Ill	35.5
Chicago, Milwaukee & St. Paul Ry	Chicago & Council Bluffs	Elgin, Ill	36.7
Chicago, Milwaukee & St. Paul Ry	Chicago & Evanston	Sheridan Park, Ill	8.0
Chicago, Rock Island & Pacific Ry	Chicago	Joliet, Ill	36.7
Grand Trunk Western Ry	Chicago & Valparaiso	Valparaiso, Ind	55.8
Illinois Central R. R	Illinois	Matteson, Ill	28.0
Illinois Central R. R	Illinois	So. Chicago, Ill	12.6
Illinois Central R. R	Illinois	Blue Island, Ill	18.7
Illinois Central R. R	Wisconsin	Addison, Ill	24.2
Lake Shore & Michigan Southern Ry	Western	Chesterton, Ind	41.1
Minneapolis, St. Paul & Sault Ste. Marie Ry	Chicago	Mukwonaga, Wis	88.9
Pittsburgh, Fort Wayne & Chicago Ry	Chicago Terminal	Valparaiso, Ind	43.6
Wabash Railroad	Decatur	Manhattan, Ill	39.9



The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals
122 Michigan Boulevard, Chicago

Form No.
31

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CHICAGO TERMINAL
Passenger Traffic in Suburban Territory and To, From and Through Chicago,
Each Year, 1903 to 1912, inclusive.

Illinois Central R.R. Co. Chicago, Ill., March, 3 1913

Instructions:

(1) Suburban Tickets: All tickets between Chicago and all Suburban Stations within the suburban limits, as defined by the operating company, such limits to be indicated by the outermost station.

(2) Other Tickets: All tickets (other than Suburban) from, to or through Chicago Depot. This may be obtained by doubling the number of tickets from Chicago Depot, including tickets for passengers coming on to the road at Chicago. This is not to include tickets for passengers coming into Chicago over the reporting companies' lines and passing through Chicago, which need not be reported.

(3) Where there is more than one suburban line or operating division, the Suburban and Other Tickets are, if practicable, to be reported separately for each suburban line or operating division.

Year	Line or Division	Suburban Tickets		Other Tickets
		Outermost Station	Number	Number
1903	Illinois Division	Flossmoor, Blue	12,996,289	598,296
1904	" "	Island + So. Chicago	14,094,656	573,470
1905	" "	do.	12,954,919	646,426
1906	" "	do.	13,439,354	540,534
1907	" "	do	13,964,621	603,930
1908	" "	do.	12,631,166	638,868
1909	" "	do	11,716,987	637,530
1910	" "	do.	13,168,126	695,132
1911	" "	do	13,745,952	773,668
1912	" "	Matteson, Blue	13239,151	769,694
Total		Island + So. Chicago	131,951,221	6,476,548
1903	Wisconsin Division	Addison	482,389	
1904	" "	"	595,565	
1905	" "	"	455,116	
1906	" "	"	100,904	
1907	" "	"	99,391	
1908	" "	"	72,815	
1909	" "	"	50,864	
1910	" "	"	54,264	
1911	" "	"	87,489	
1912	" "	"	62,668	
Total			2,061,465	
1903	Other Tickets: These figures include Big Four			
1904				
1905	business and were arrived at by doubling the			
1906				
1907	number of passengers from Chicago. They			
1908				
1909	are approximately correct while the			
1910				
1911	suburban are actual.			
1912				
Total				

FIG. 432. TYPICAL RAILROAD REPORT OF THE NUMBER OF PASSENGERS CARRIED ANNUALLY
("FORM 31")

Several of the railroads failed to give the information required, either for the whole or for a part of the ten years involved. In such cases, estimated values were determined by interpolation, by comparison with the reports of other railroads or by reference to reports made to the Illinois Railroad and Warehouse Commission. The specific instances are as follows:

Atchison, Topeka & Santa Fe Ry.: Through passengers were estimated for all years except 1906 and 1912.

Baltimore & Ohio R. R.: Through passengers were estimated for all years.

Baltimore & Ohio Chicago Terminal R. R.: Suburban passengers were estimated for the years 1903 to 1906, inclusive.

Chesapeake & Ohio Ry. of Indiana: Through and suburban passengers were estimated for the years 1907 to 1909, inclusive. These passengers were carried by the Chicago, Cincinnati & Louisville Ry., which was succeeded by the Chesapeake & Ohio Ry. of Indiana. This road does not operate suburban trains but suburban fares apply to Hammond, Ind.

Chicago & Alton R. R.: Total passengers were reported by this road for 1903 and 1904; through and suburban passengers were estimated, but their sum equals the total reported.

Chicago, Burlington & Quincy R. R.: Through passengers and suburban passengers were estimated for the years 1903, 1904 and 1905.

Chicago Great Western R. R.: Through and suburban passengers were estimated for the years 1903 to 1909, inclusive. This road does not operate suburban trains, but suburban fares apply to St. Charles, Ill.

Chicago, Indiana & Southern R. R.: Does not operate suburban trains but reported passengers for Lake Shore & Michigan Southern suburban trains which operate over Chicago, Indiana & Southern tracks.

Chicago, Indianapolis & Louisville Ry.: Through passengers were estimated for 1903.

Chicago, Milwaukee & St. Paul Ry.: Through passengers and suburban passengers were estimated for the years 1903, 1904 and 1905.

Chicago, Rock Island & Pacific Ry.: Through and suburban passengers were estimated for the years 1903, 1904 and 1905.

Grand Trunk Western Ry.: Through passengers were estimated for all years.

Illinois Central Railroad: The through passengers of the Cleveland, Cincinnati, Chicago & St. Louis Ry., are included in the report of through passengers for this road.

Lake Shore & Michigan Southern Ry.: Through passengers and suburban passengers were estimated for the years 1903 and 1904.

Minneapolis, St. Paul & Sault Ste. Marie Ry.: Through passengers and suburban passengers were estimated for the years 1903 to 1907, inclusive. These passengers were carried by the Wisconsin Central Ry., which was succeeded by this road. No suburban trains are operated but suburban fares apply to Mukwonaga, Wis.

New York, Chicago & St. Louis R. R.: Through passengers were estimated for all years.

Pere Marquette R. R.: Through passengers were estimated for all years.

Pittsburgh, Cincinnati, Chicago & St. Louis Ry.: Through passengers were estimated for the years 1903 and 1904.

Pittsburgh, Fort Wayne & Chicago Ry.: Total passengers were reported, and through and suburban passengers estimated from this total.

Wabash R. R.: Through passengers and suburban passengers were estimated from 1903 to 1908, inclusive.

Statements relating to the number of through passengers, suburban passengers, and through and suburban passengers carried by each railroad are presented by tables CCIX, CCX and CCXI.

These tables show that during the period from 1903 to 1912, inclusive, the number of through passengers handled on the Chicago terminals increased 56.4 per cent. During the same period, the number of suburban passengers increased 26.9 per cent and the total number of all passengers increased 29.6 per cent. However, some of the railroads show a decrease in the number of passengers carried in recent years.

203.06 Changing Conditions Affecting Suburban Passenger Traffic: Suburban passenger traffic is generally dependent upon the population of the district served. In Chicago, its growth is probably dependent upon the increase in population of the suburban towns rather than upon that of the city. Statistics show that the surface and elevated railways are absorbing the short haul passenger traffic and are thereby forcing the steam roads to depend upon the long haul business. This tendency is manifested by the increase in the average length of haul of suburban passengers on three representative steam railroads, as shown by the following:

	INCREASE PER CENT
Illinois Central R. R. (1903 to 1912)	12
Chicago, Rock Island & Pacific Ry. (1903 to 1912)	25
Chicago & Western Indiana R. R. (1905 to 1912)	14

The rate of increase of suburban passenger traffic on the steam railroads of Chicago has diminished in recent years, principally because of the advantages of the electric surface and elevated

TABLE CCIX. NUMBER OF THROUGH PASSENGERS HANDLED BY STEAM RAILROADS IN THE CHICAGO TERMINALS

Railroad	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	*Increase from 1903 to 1912	
											Passengers	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13
Atchison, Topeka & Santa Fe Ry	273,000	284,000	307,000	329,457	295,000	371,000	359,000	384,000	383,000	393,320	120,320	44.1
Baltimore & Ohio R. R.	136,900	160,500	173,000	142,000	144,500	155,000	164,000	173,500	183,500	187,000	50,100	36.5
Baltimore & Ohio Chicago Terminal R. R.	....	....	....	....	....	....	....	....	....	....	....	......
Chesapeake & Ohio Ry. of Indiana	....	....	....	....	7,800	33,800	42,400	51,000	51,889	58,520	50,720†	650.0†
Chicago & Alton R. R.	354,938	397,820	408,157	363,695	361,576	432,951	478,364	462,911	507,626	491,535	136,597	38.5
Chicago & Eastern Illinois R. R.	183,459	182,223	194,947	213,117	218,962	251,804	271,429	310,599	316,120	354,540	171,081	93.2
Chicago & Erie R. R.	186,100	190,500	194,500	214,000	228,800	221,000	201,700	192,700	196,600	198,400	12,300	6.6
Chicago & North Western Ry.	1,755,199	1,743,469	2,058,781	2,270,072	2,285,246	1,988,496	2,023,436	2,127,769	2,118,116	2,330,155	574,956	32.7
Chicago & Western Indiana R. R.	....	....	....	....	....	....	....	....	....	....	....	......
Chicago, Burlington & Quincy R. R	410,000	400,000	450,000	498,047	597,450	612,170	694,763	748,694	857,410	775,366	365,366	89.1
Chicago Great Western R. R	197,300	190,000	209,600	240,500	263,000	143,200	136,300	139,604	129,322	126,214	71,086‡	36.0
Chicago, Indiana & Southern R. R	....	....	....	10,326	16,964	17,972	40,020	44,478	33,026	37,770	27,444¶	266.0‡
Chicago, Indianapolis & Louisville Ry	210,000	249,234	309,042	347,888	428,468	378,330	332,614	356,364	377,484	295,988	85,988	40.8¶
Chicago, Milwaukee & St. Paul Ry	556,000	609,000	659,000	711,890	855,070	944,670	871,706	1,003,456	1,055,620	1,072,474	516,474	92.8
Chicago, Rock Island & Pacific Ry	196,000	250,000	262,000	296,018	401,238	471,170	510,998	546,188	589,482	554,736	358,736	182.6
Grand Trunk Western Ry	132,900	164,500	214,000	359,500	352,700	209,800	246,900	235,100	285,800	331,200	198,300	149.1
Illinois Central R. R	597,296	573,470	646,426	540,534	603,930	638,868	637,530	695,132	773,668	769,694	172,398	28.8
Lake Shore & Michigan Southern Ry	418,000	534,000	462,298	513,414	552,548	566,132	677,354	719,422	762,597	806,352	388,352	92.8
Michigan Central R. R	445,692	336,170	360,000	408,558	458,818	451,074	502,462	558,246	588,960	625,696	180,004	40.4
Minneapolis, St. Paul & Sault Ste. Marie Ry	125,500	133,500	140,000	154,000	163,500	157,888	161,660	182,624	194,710	190,342	64,842	51.6
New York, Chicago & St. Louis R. R	191,200	257,600	264,200	256,100	258,600	256,300	255,100	265,500	267,500	265,500	74,300	38.9
Pere Marquette R. R	66,000	99,000	131,000	164,000	197,600	226,100	263,600	299,600	313,300	312,700	246,700	374.0
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	171,100	178,700	182,383	198,245	238,846	250,585	250,132	264,379	255,083	278,738	107,638	62.8
Pittsburgh, Fort Wayne & Chicago Ry	248,000	254,000	273,209	334,161	369,737	328,731	349,068	403,233	413,714	383,626	135,626	54.6
Wabash R. R	238,000	244,000	261,000	219,000	208,000	228,000	229,833	274,558	282,445	259,917	21,917	9.2
Totals	7,092,584	7,431,686	8,160,543	8,784,522	9,508,353	9,335,041	9,700,369	10,439,087	10,936,972	11,099,783	4,007,199	56.4

* Blanks in this table indicate that there were no through passengers handled by the road in question. † Increase 1907 to 1912. ‡ Decrease. ¶ Increase 1906 to 1912.

TABLE CCX. NUMBER OF SUBURBAN PASSENGERS HANDLED BY STEAM RAILROADS IN THE CHICAGO TERMINALS*

Railroad	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	Increase from 1903 to 1912	
											Passengers	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13
Atchison, Topeka & Santa Fe Ry	....	....	....	....	....	....	....	....	....	....	....	......
Baltimore & Ohio R. R.	....	....	....	....	....	....	....	....	....	....	....	......
Baltimore & Ohio Chicago Terminal R. R.	708,000	625,000	456,000	510,000	451,377	329,428	341,072	396,173	332,183	252,500	455,500†	64.3†
Chesapeake & Ohio Ry. of Indiana	....	....	....	....	....	3,600	4,400	5,400	5,460	5,795	2,195‡	61.0‡
Chicago & Alton R. R	131,100	147,000	146,683	161,157	155,157	145,692	167,811	184,073	163,032	154,054	22,954	17.5
Chicago & Eastern Illinois R. R	1,202,908	728,012	397,658	453,277	441,075	397,591	416,827	520,991	482,773	472,777	730,131†	60.7†
Chicago & Erie R. R.	....	....	....	....	....	....	....	....	....	....	....	......
Chicago & North Western Ry.	9,946,290	10,307,575	10,957,274	11,766,370	12,243,939	10,839,365	10,984,843	11,176,376	11,581,690	12,252,160	2,305,870	23.2
Chicago & Western Indiana R. R.	....	....	1,653,405	1,815,981	1,585,249	1,260,455	1,281,107	1,253,115	1,366,772	1,472,345	181,060¶	10.9¶
Chicago, Burlington & Quincy R. R	2,550,000	2,510,000	2,830,000	3,096,577	3,234,303	3,124,957	3,313,283	3,545,875	4,114,477	4,104,556	1,554,556	60.9
Chicago Great Western R. R	13,700	13,000	13,400	16,500	18,000	9,800	9,200	9,500	6,580	5,430	8,270†	60.3†
Chicago, Indiana & Southern R. R	....	....	....	15,797	71,063	89,479	88,684	52,612	49,015	53,563	37,766§	239.0§
Chicago, Indianapolis & Louisville Ry	....	....	....	....	....	....	....	....	....	....	....	......
Chicago, Milwaukee & St. Paul Ry	587,000	646,000	696,000	752,435	794,300	607,630	540,885	429,915	454,595	448,750	138,250†	23.5†
Chicago, Rock Island & Pacific Ry	2,984,000	3,810,000	3,998,000	4,512,158	4,218,077	3,980,063	4,452,421	4,527,279	4,545,461	4,488,971	1,504,971	50.4
Grand Trunk Western Ry	836,000	835,000	832,000	807,000	767,000	719,000	747,000	860,000	815,000	765,000	71,000†	8.5†
Illinois Central R. R	13,478,678	14,690,221	13,410,035	13,540,258	14,064,012	12,703,981	11,767,851	13,222,390	13,833,441	13,301,819	176,859†	1.3†
Lake Shore & Michigan Southern Ry	1,092,000	1,186,000	1,025,080	1,936,227	2,746,535	2,924,230	3,026,114	3,299,098	3,564,104	3,813,591	2,721,591	249.0
Michigan Central R. R	....	....	....	....	....	....	....	....	....	....	....	......
Minneapolis, St. Paul & Sault Ste. Marie Ry	5,000	5,300	5,500	6,000	6,500	6,098	6,766	8,854	7,904	8,810	3,810	76.2
New York, Chicago & St. Louis R. R	....	....	....	....	....	....	....	....	....	....	....	......
Pere Marquette R. R	....	....	....	....	....	....	....	....	....	....	....	......
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	....	....	....	....	....	....	....	....	....	....	....	......
Pittsburgh, Fort Wayne & Chicago Ry	118,000	120,000	129,000	157,700	174,600	155,400	165,000	189,000	195,400	181,500	63,500	53.7
Wabash R. R	326,000	334,000	358,000	301,000	284,000	312,000	314,182	344,773	333,668	337,972	11,972	3.7
Totals	33,978,676	35,957,108	36,908,035	39,848,437	41,255,187	37,608,771	37,630,446	40,025,424	41,851,555	42,119,593	9,140,917	26.9

* Blanks in this table indicate that there were no suburban passengers handled by the road in question. † Decrease. ‡ Increase 1908 to 1912. ¶ Decrease 1905 to 1912. § Increase 1906 to 1912.

TABLE CCXI. NUMBER OF THROUGH AND SUBURBAN PASSENGERS HANDLED BY STEAM RAILROADS IN THE CHICAGO TERMINALS

Railroad	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	Increase from 1903 to 1912	
											Passengers	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13
Atchison. Topeka & Santa Fe Ry	273.000	284.000	307.000	329,457	295.000	371,000	359.000	384,000	383,000	393.320	120,320	44.1
Baltimore & Ohio R. R	136,900	160.500	173.000	142.000	144.500	155,000	164,000	173.500	183.500	187,000	50.100	36.5
Baltimore & Ohio Chicago Terminal R. R	708,000	625.000	456.000	510,000	451.377	329,428	341.072	396,173	332.183	252.500	455,500*	64.3*
Chesapenke & Ohio Ry. of Indiana	....	....	....	....	7.800	37.400	46.800	56.400	57.349	64.315	56,515†	724.0†
Chicago & Alton R. R	486.038	544,820	554.840	524,852	516.733	578.643	646.175	647,014	670.658	645.589	159.551	32.8
Chicago & Eastern Illinois R. R	1.386.367	910,235	592.605	666.394	660.037	649.395	688,256	831.590	798,893	827.317	559,050*	40.4*
Chicago & Erie R. R	186.100	190.500	194,500	214.000	228.800	221.000	201.700	192.700	196,600	198.400	12,300	6.6
Chicago & North Western Ry	11.701.489	12.051.044	13,016,055	14.036.442	14.529.185	12,827.861	13,008,279	13,304,145	13,699,806	14,582.315	2,880,826	24.6
Chicago & Western Indiana R. R	....	....	1.653.405	1.815.981	1.585.249	1.260.455	1,284.107	1.253.115	1.366,772	1.472,345	181,060‡	10.9‡
Chicago, Burlington & Quincy R. R	2,960,000	2,910,000	3,280.000	3.594.624	3,831,753	3,737,129	4.008.046	4.294.569	4.971.887	4.879.922	1.919,922	64.8
Chicago Great Western R. R	211,000	203,000	223,000	257,000	281.000	153.000	145,500	149,104	135.902	131,644	79,356*	37.6*
Chicago, Indiana & Southern R. R	....	....	....	26.123	88.027	107.451	128,704	97.090	82,041	91,333	65,210¶	249.0¶
Chicago, Indinnapolis & Louisville Ry	210,000	249.234	309.042	347,888	428.468	378,330	332,614	356.364	377.484	295,988	85,988	40.8
Chicago, Milwaukee & St. Paul Ry	1,143,000	1,255,000	1.355,000	1,464.325	1,649.370	1.552.300	1.412.591	1,433.371	1,510.215	1.521.224	378.224	33.1
Chicago. Rock Island & Pacific Ry	3.180,000	4.060.000	4.260.000	4.808.176	4.619,315	4.451.233	4.963.419	5.073.467	5,134.943	5,043.707	1.863,707	58.6
Grand Trunk Western Ry	968.900	999.500	1,016.000	1.166.500	1.119.700	928,800	993.900	1.095.100	1.100.800	1,096.200	127.300	13.1
Illinois Central R. R	14,075,974	15,263.691	14.056,461	14.080,792	14.667.942	13.342.849	12.405.381	13.917,522	14,607,109	14.071.513	4,461*	0.1*
Lake Shore & Michigan Southern Ry	1,510,000	1.720.000	1,487.378	2.449.641	3,299.083	3,490.362	3.703.468	4,018,520	4.326.701	4,619.943	3,109.943	206.0
Michigan Central R. R	445.692	336.170	360.000	408,558	458,818	451.074	502.462	558.246	588,960	625.696	180.004	40.4
Minneapolis, St. Paul & Sault Ste. Marie Ry	130.500	138,800	145.500	160.000	170.000	163.986	168.426	191,472	192,614	199,152	68.652	52.6
New York, Chicago & St. Louis R. R	191,200	257,600	264.200	256,100	258.600	256,300	255.100	265,500	267.500	265.500	74.300	38.9
Pere Marquette R. R	66,000	99.000	131.000	164,000	197,600	226.100	263,600	299,600	313.300	312.700	246,700	374.0
Pittsburgh, Cincinnati. Chicago & St. Louis Ry	171.100	178.700	182.383	198.245	238,846	250.585	250,132	264.379	255.083	278.738	107,638	62.8
Pittsburgh, Fort Wayne & Chicago Ry	366.000	374,000	402,209	491.861	544,337	484,131	514,068	592.233	609.114	565.126	199,126	54.4
Wabash R. R	564.000	578.000	619.000	520.000	492.000	540,000	544.015	619,331	616.113	597,889	33.889	6.0
Totals	41.071,260	43,388,794	45.068,578	48,632,959	50,763.540	46.943,812	47,330,815	50.464.511	52.788.527	53,219,376	12.148.116	29.6

* Decrease. † Increase 1907 to 1912. ‡ Decrease 1905 to 1912. ¶ Increase 1906 to 1912

lines as regards lower fares, more frequent schedules, transfer privileges and ability to deliver passengers in closer proximity to their destination. The extended use of the automobile has probably also contributed to this change. The increases in passenger traffic shown by the suburban service of the steam railroads, by the entire service of the elevated railways and by the service of the surface lines of Chicago for the period from 1903 to 1912, inclusive, are set forth in the following:

	INCREASE PER CENT
Suburban traffic of steam railroads	26.9
Traffic of elevated railways	47.2
Traffic of surface lines	111.0*

203.07 Conclusions with Reference to the Increase in Number of Passengers: The annual increase in the number of passengers carried by the steam railroads of Chicago is shown graphically by fig. 433.

Superimposed upon the curves of actual increase from 1903 to 1912 are shown curves of predicted increase subsequent to 1912 plotted from the following equations:

Through passengers:

$$P = 1{,}000{,}000\ (7.09 + 0.444\ [Y-1])$$

Suburban passengers:

$$P = 1{,}000{,}000\ (33.8\ Y^{0.095})$$

Through and suburban passengers:

$$P = 1{,}000{,}000\ (39.6\ Y^{0.128})$$

"P" represents the number of passengers carried and "Y" the number of years succeeding 1902, 1903 being year one, 1904, year two, and so on.

By the first equation it is seen that, following the year 1903, the number of through passengers increased approximately by increments of 444,000 per year, the number of suburban passengers increased as the 0.095th power of the number of years, and the total number of passengers increased as the 0.128th power of the number of years.

The relation between the increase in the population of the United States and the increase in the number of through passengers handled by the steam railroads of Chicago is a matter of some interest. Statements of population issued by the United States Bureau of Census indicate an increase in the population of the country of 18.3 per cent for the period from 1903 to 1912, inclusive. This percentage of increase corresponds to

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* From figures furnished by the Board of Supervising Engineers of the City of Chicago.

FIG. 433. ANNUAL INCREASE IN THE NUMBER OF PASSENGERS CARRIED BY THE STEAM RAILROADS OF CHICAGO

an increment of population of about 1,650,000 per year. The increase in the number of through passengers handled by the Chicago terminals during the same period was 27 per cent of this annual increase in population of the United States, or approximately 444,000 per year, so that each million of increase in population of the United States has been accompanied by an increase of approximately 270,000 through passengers in Chicago.

From the foregoing statements, it is obvious that the increase in the number of passengers carried by the steam railroads of Chicago during the ten-year period ending with 1912 has been affected by various influences, the summation of which, both positive and negative, is taken into account by the curves, fig. 433, and the equations derived from them. Both constitute a true reflection of changes which actually occurred prior to 1912. Assuming that the same law of increase will hold for the ten years following 1912, the rate of growth will be that indicated by the extended curves, fig. 433, and by the numerical values which are presented in table CCXII.

TABLE CCXII. ESTIMATED FUTURE GROWTH OF PASSENGER TRAFFIC ON THE CHICAGO TERMINALS

Year	Through Passengers	Per Cent Incr. Over 1912	Suburban Passengers	Per Cent Incr. Over 1912	Total Passengers	Per Cent Incr. Over 1912
1	2	3	4	5	6	7
1912	11,099,783	......	42,119,593	......	53,219,376	......
1913	11,540,000	4.0	42,600,000	1.2	54,140,000	1.7
1914	11,990,000	8.1	43,000,000	2.3	54,990,000	3.4
1915	12,430,000	12.2	43,300,000	3.0	55,730,000	4.8
1916	12,880,000	16.2	43,600,000	3.6	56,480,000	6.2
1917	13,320,000	20.2	43,900,000	4.4	57,220,000	7.5
1918	13,770,000	24.2	44,200,000	5.0	57,970,000	8.9
1919	14,210,000	28.3	44,400,000	5.6	58,610,000	10.1
1920	14,660,000	32.3	44,700,000	6.2	59,360,000	11.5
1921	15,100,000	36.3	44,900,000	6.8	60,000,000	12.8
1922	15,540,000	40.3	45,100,000	7.2	60,640,000	14.0

Reviewing the numerical values of table CCXII, it is seen that the estimate of growth indicates that the number of through passengers arriving at and departing from the steam railroad terminals of Chicago in 1922 will be 40.3 per cent greater than the number in 1912. The number of suburban passengers will increase, but the rate of increase will continue to diminish. This service will be 7.2 per cent greater in 1922 than in 1912. The total number of all passengers arriving and departing will be 14 per cent greater in 1922 than in 1912.

203.08 Number of Passenger Trains: The number of scheduled passenger trains on each

TABLE CCXIII. AVERAGE NUMBER OF WEEK DAY SCHEDULED THROUGH PASSENGER TRAINS HANDLED IN THE CHICAGO TERMINALS*

Railroad	1903			1904			1905			1906			1907			1908			1909			1910			1911			1912			Increase in Total 1903 to 1912	
	Arriving	Departing	Total	Arriving	Departing	Total	Arriving	Departing	Total	Arriving	Departing	Total	Arriving	Departing	Total	Arriving	Departing	Total	Arriving	Departing	Total	Arriving	Departing	Total	Arriving	Departing	Total	Arriving	Departing	Total	Trains per Day	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Atchison, Topeka & Santa Fe Ry	7	6	13	7	6	13	8	7	15	8	7	15	8	7	15	8	7	15	8	7	15	8	7	15	8	8	16	8	8	16	3	23.1
Baltimore & Ohio R. R.	4	5	9	4	5	9	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	6	6	12	3	33.3
Baltimore & Ohio Chicago Terminal R. R.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chesapeake & Ohio Ry. of Indiana	....	....	....	....	....	....	....	....	....	....	....	....	2	2	4	2	2	4	2	2	4	2	2	4	2	2	4	3	3	6	2†	50.0†
Chicago & Alton R. R.	7	7	14	8	8	16	8	8	16	8	9	17	7	7	14	8	8	16	9	8	17	9	8	17	8	8	16	7	8	15	1	7.1
Chicago & Eastern Illinois R. R.	7	8	15	7	7	14	8	8	16	8	8	16	10	10	20	10	10	20	10	10	20	10	10	20	10	10	20	11	11	22	7	46.6
Chicago & Erie R. R.	5	5	10	6	6	12	7	7	14	7	7	14	8	8	16	7	7	14	7	7	14	6	6	12	6	5	11	6	5	11	1	10.0
Chicago & North Western Ry	51	55	106	52	55	107	55	56	111	59	61	120	62	62	124	60	61	121	68	68	136	70	71	141	73	72	145	70	71	141	35	33.0
Chicago & Western Indiana R. R.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chicago, Burlington & Quincy R. R.	11	12	23	11	12	23	11	11	22	14	14	28	14	14	28	15	15	30	15	15	30	15	15	30	15	15	30	16	15	31	8	34.7
Chicago Great Western R. R.	6	6	12	5	5	10	5	5	10	5	5	10	6	6	12	6	6	12	5	5	10	4	4	8	4	4	8	4	4	8	4‡	33.3‡
Chicago, Indiana & Southern R. R.	....	....	....	....	....	....	....	....	....	2	2	4	2	2	4	2	2	4	3	3	6	3	3	6	3	3	6	3	3	6	2¶	50.0¶
Chicago, Indianapolis & Louisville Ry	5	5	10	6	6	12	6	6	12	6	6	12	6	6	12	6	6	12	6	6	12	6	6	12	7	7	14	7	7	14	4	40.0
Chicago, Milwaukee & St. Paul Ry	23	23	46	24	23	47	26	27	53	27	26	53	26	25	51	26	25	51	26	26	52	26	27	53	27	28	55	28	27	55	9	19.5
Chicago, Rock Island & Pacific Ry	13	13	26	13	13	26	12	15	27	13	16	29	16	17	33	16	17	33	16	17	33	19	19	38	20	20	40	20	20	40	14	53.8
Grand Trunk Western Ry	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	6	6	12	6	6	12	6	6	12	6	6	12	7	7	14	4	40.0
Illinois Central R. R.	17	17	34	18	18	36	17	17	34	19	18	37	19	19	38	19	19	38	19	20	39	21	21	42	21	21	42	22	22	44	10	29.4
Lake Shore & Michigan Southern Ry	11	10	21	12	10	22	11	10	21	14	12	26	14	13	27	13	12	25	14	13	27	14	14	28	16	16	32	16	16	32	11	52.3
Michigan Central R. R.	10	10	20	11	11	22	11	11	22	12	12	24	12	12	24	12	11	23	12	12	24	12	12	24	13	13	26	13	14	27	7	35.0
Minneapolis, St. Paul & Sault Ste. Marie Ry	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	6	6	12	7	7	14	4	40.0
New York, Chicago & St. Louis R. R.	3	3	6	3	3	6	3	3	6	3	3	6	3	3	6	3	3	6	3	3	6	3	3	6	3	3	6	3	3	6	0	0.0
Pere Marquette R. R.	3	4	7	4	4	8	4	4	8	4	4	8	5	5	10	4	4	8	4	4	8	5	5	10	5	5	10	5	5	10	3	42.8
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	7	7	14	7	7	14	6	6	12	7	7	14	7	7	14	7	7	14	7	7	14	8	8	16	8	8	16	7	7	14	0	0.0
Pittsburgh, Fort Wayne & Chicago Ry	8	8	16	9	8	17	10	10	20	11	11	22	12	11	23	11	11	22	11	11	22	12	11	23	14	12	26	14	12	26	10	62.5
Wabash Railroad	9	9	18	9	9	18	10	10	20	10	9	19	9	9	18	9	8	17	9	8	17	9	8	17	9	8	17	8	7	15	3‡	16.6‡
Totals	217	223	440	226	226	452	233	236	469	252	252	504	263	260	523	260	257	517	270	268	538	278	276	554	289	285	574	291	288	579	139	31.6

* Blanks in this table indicate that the road in question did not operate through passenger trains in the year referred to. † Increase 1907 to 1912. ‡ Decrease. ¶ Increase 1906 to 1912.

TABLE CCXIV. AVERAGE NUMBER OF WEEK DAY SCHEDULED SUBURBAN PASSENGER TRAINS HANDLED IN THE CHICAGO TERMINALS*

Railroad	1903			1904			1905			1906			1907			1908			1909			1910			1911			1912			Increase in Total 1903 to 1912	
	Arriving	Departing	Total	Arriviog	Departing	Total	Arriving	Departing	Total	Arriving	Departing	Total	Arriving	Departing	Total	Arriving	Departing	Total	Arriviog	Departing	Total	Arriving	Departing	Total	Arriving	Departiog	Total	Arriving	Departiog	Total	Trains per Day	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Atchison, Topeka & Santa Fe Ry	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Baltimore & Ohio R. R.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Baltimore & Ohio Chicago Terminal R. R.	7	7	14	6	6	12	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	6†	42.8†
Chesapeake & Ohio Ry. of Indiana	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chicago & Alton R. R.	3	3	6	2	1	3	1	1	2	1	0	1	1	1	2	1	1	2	1	1	2	1	1	2	1	1	2	2	1	3	3†	50.0†
Chicago & Eastern Illinois R. R.	10	10	20	7	7	14	2	2	4	2	2	4	2	2	4	2	2	4	1	2	3	1	2	3	1	2	3	1	2	3	17†	85.0†
Chicago & Erie R. R.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chicago & North Western Ry.	86	83	169	82	80	162	93	91	184	99	102	201	102	102	204	101	99	200	102	107	209	92	91	183	95	95	190	102	102	204	35	20.7
Chicago & Western Indiana R. R.	....	....	....	5	5	10	14	15	29	14	16	30	13	14	27	12	12	24	12	14	26	14	16	30	17	19	36	17	19	36	26‡	260.0‡
Chicago, Burlington & Quincy R. R.	33	34	67	33	33	66	33	34	67	33	33	66	33	34	67	34	34	68	34	34	68	34	34	68	34	34	68	32	32	64	3†	4.5†
Chicago Great Western R. R.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chicago, Indiana & Southern R. R.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chicago, Indianapolis & Louisville Ry.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chicago, Milwaukee & St. Paul Ry.	22	22	44	19	20	39	20	21	41	20	21	41	20	21	41	18	19	37	16	16	32	17	16	33	16	16	32	15	16	31	13†	29.5†
Chicago, Rock Island & Pacific Ry.	29	30	59	39	38	77	39	38	77	41	38	79	40	39	79	39	38	77	42	42	84	39	40	79	37	37	74	35	35	70	11	18.6
Grand Trunk Western Ry.	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	0	0
Illinois Central R. R.	125	127	252	125	126	251	127	127	254	132	131	263	130	132	262	133	132	265	132	131	263	134	134	268	137	136	273	145	144	289	37	14.7
Lake Shore & Michigan Southern Ry.	33	33	66	30	31	61	26	25	51	25	24	49	27	27	54	26	26	52	22	22	44	20	21	41	21	21	42	20	20	40	26†	39.4†
Michigan Central R. R.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Minneapolis, St. Paul & Sault Ste. Marie Ry.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
New York, Chicago & St. Louis R. R.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pere Marquette R. R.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pittsburgh, Fort Wayne & Chicago Ry.	9	9	18	11	11	22	11	11	22	11	11	22	11	11	22	11	11	22	11	11	22	12	12	24	12	12	24	12	12	24	6	33.3
Wabash Railroad	6	6	12	6	6	12	6	6	12	5	5	10	6	6	12	6	6	12	6	6	12	6	6	12	6	6	12	7	6	13	1	8.3
Totals	367	368	735	369	368	737	380	379	759	391	391	782	393	397	790	391	388	779	387	394	781	378	381	759	385	387	772	396	397	793	58	7.9

* Blanks in this table indicate that the road in question did not operate suburban passenger trains in the year referred to.

† Decrease.

‡ Increase 1904 to 1912.

TABLE CCXV. AVERAGE NUMBER OF WEEK DAY SCHEDULED THROUGH AND SUBURBAN PASSENGER TRAINS HANDLED IN THE CHICAGO TERMINALS

Railroad	1903			1904			1905			1906			1907			1908			1909			1910			1911			1912			Increase in Total 1903 to 1912	
	Arriving	Departing	Total	Arriviog	Departing	Total	Arriving	Departing	Total	Arriviog	Departiog	Total	Arriving	Departing	Total	Arriving	Departing	Total	Arriving	Departiog	Total	Arriviog	Departing	Total	Arriving	Departing	Total	Arriving	Departing	Total	Trains Per Day	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Atchison, Topeka & Santa Fe Ry	7	6	13	7	6	13	8	7	15	8	7	15	8	7	15	8	7	15	8	7	15	8	7	15	8	8	16	8	8	16	3	23.1
Baltimore & Ohio R. R.	4	5	9	4	5	9	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	6	6	12	3	33.3
Baltimore & Ohio Chicago Terminal R. R.	7	7	14	6	6	12	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	6*	42.8*
Chesapeake & Ohio Ry. of Indiana	....	....	....	....	....	....	....	....	....	....	....	....	2	2	4	2	2	4	2	2	4	2	2	4	2	2	4	3	3	6	2†	50.0†
Chicago & Alton R. R.	10	10	20	10	9	19	9	9	18	9	9	18	8	8	16	9	9	18	10	9	19	10	9	19	9	9	18	9	9	18	2*	10.0*
Chicago & Eastern Illinois R. R.	17	18	35	14	14	28	10	10	20	10	10	20	12	12	24	12	12	24	11	12	23	11	12	23	11	12	23	12	13	25	10*	28.6*
Chicago & Erie R. R.	5	5	10	6	6	12	7	7	14	7	7	14	8	8	16	7	7	14	7	7	14	6	6	12	6	5	11	6	5	11	1	10.0
Chicago & North Western Ry.	137	138	275	134	135	269	148	147	295	158	163	321	164	164	328	161	160	321	170	175	345	162	162	324	168	167	335	172	173	345	70	25.5
Chicago & Western Indiana R. R.	....	....	....	5	5	10	14	15	29	14	16	30	13	14	27	12	12	24	12	14	26	14	16	30	17	19	36	17	19	36	26‡	260.0‡
Chicago, Burlington & Quincy R. R.	44	46	90	44	45	89	44	45	89	47	47	94	47	48	95	49	49	98	49	49	98	49	49	98	49	49	98	48	47	95	5	5.6
Chicago Great Western R. R.	6	6	12	5	5	10	5	5	10	5	5	10	6	6	12	6	6	12	5	5	10	4	4	8	4	4	8	4	4	8	4*	33.3*
Chicago, Indiana & Southern R. R.	....	....	....	....	....	....	....	....	....	2	2	4	2	2	4	2	2	4	3	3	6	3	3	6	3	3	6	3	3	6	2¶	50.0¶
Chicago, Indianapolis & Louisville Ry.	5	5	10	6	6	12	6	6	12	6	6	12	6	6	12	6	6	12	6	6	12	6	6	12	7	7	14	7	7	14	4	40.0
Chicago, Milwaukee & St. Paul Ry.	45	45	90	43	43	86	46	48	94	47	47	94	46	46	92	44	44	88	42	42	84	43	43	86	43	44	87	43	43	86	4*	4.4*
Chicago, Rock Island & Pacific Ry.	42	43	85	52	51	103	51	53	104	54	54	108	56	56	112	55	55	110	58	59	117	58	59	117	57	57	114	55	55	110	25	29.4
Grand Trunk Western Ry.	9	9	18	9	9	18	9	9	18	9	9	18	9	9	18	10	10	20	10	10	20	10	10	20	10	10	20	11	11	22	4	22.2
Illinois Central R. R.	142	144	286	143	144	287	144	144	288	151	149	300	149	151	300	152	151	303	151	151	302	155	155	310	158	157	315	167	166	333	47	16.4
Lake Shore & Michigan Southern Ry.	44	43	87	42	41	83	37	35	72	39	36	75	41	40	81	39	38	77	36	35	71	34	35	69	37	37	74	36	36	72	15*	17.2*
Michigan Central R. R.	10	10	20	11	11	22	11	11	22	12	12	24	12	12	24	12	11	23	12	12	24	12	12	24	13	13	26	13	14	27	7	35.0
Minneapolis, St. Paul & Sault Ste. Marie Ry.	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	5	5	10	6	6	12	7	7	14	4	40.0
New York, Chicago & St. Louis R. R.	3	3	6	3	3	6	3	3	6	3	3	6	3	3	6	3	3	6	3	3	6	3	3	6	3	3	6	3	3	6	0	0.0
Pere Marquette R. R.	3	4	7	4	4	8	4	4	8	4	4	8	5	5	10	4	4	8	4	4	8	5	5	10	5	5	10	5	5	10	3	42.8
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	7	7	14	7	7	14	6	6	12	7	7	14	7	7	14	7	7	14	7	7	14	8	8	16	8	8	16	7	7	14	0	0.0
Pittsburgh, Fort Wayne & Chicago Ry.	17	17	34	20	19	39	21	21	42	22	22	44	23	22	45	22	22	44	22	22	44	24	23	47	26	24	50	26	24	50	16	47.2
Wabash Railroad	15	15	30	15	15	30	16	16	32	15	14	29	15	15	30	15	14	29	15	14	29	15	14	29	15	14	29	15	13	28	2*	6.6*
Totals	584	591	1,175	595	594	1,189	613	615	1,228	643	643	1,286	656	657	1,313	651	645	1,296	657	662	1,319	656	657	1,313	674	672	1,346	687	685	1,372	197	16.8

* Decrease.

† Increase 1907 to 1912.

‡ Increase 1904 to 1912.

¶ Increase 1906 to 1912.

road was obtained from the operating time-tables. The average number of daily trains was found by taking the average of those scheduled in time-tables for the representative months of January and July of each year. The number of trains arriving and departing on week days was determined for both through and suburban service, with results which are set forth in tables CCXIII, CCXIV and CCXV.

In these tables are shown the number of trains arriving and departing on each railroad and the total number of trains for an average week day for each year from 1903 to 1912, inclusive, as well as the increase in the total number of trains.

The rate of increase in the number of Sunday trains is greater than that of the week day trains for the period covered. This relation is shown by table CCXVI.

TABLE CCXVI. AVERAGE NUMBER OF SUNDAY TRAINS AND AVERAGE NUMBER OF WEEK DAY TRAINS HANDLED IN THE CHICAGO TERMINALS

Year	Average Number of Sunday Trains			Average Number of Week Day Trains			Ratio of the Number of Sunday Trains to the Number of Week Day Trains		
	Thro.	Sub-urban	Thro. and Sub-urban	Thro.	Sub-urban	Thro. and Sub-urban	Through Ratio Per Cent	Suburban Ratio Per Cent	Through and Suburban Ratio Per Cent
1	2	3	4	5	6	7	8	9	10
1903	337	244	581	440	735	1,175	76.7	33.2	49.4
1904	348	250	598	452	737	1,189	76.9	33.9	50.3
1905	363	265	628	469	759	1,228	77.4	34.9	51.2
1906	396	271	667	504	782	1,286	78.6	34.7	51.8
1907	416	294	710	523	790	1,313	79.5	37.2	54.0
1908	418	289	707	517	779	1,296	81.0	37.1	54.6
1909	441	288	729	538	781	1,319	81.9	36.9	55.2
1910	468	301	769	554	759	1,313	84.4	39.6	58.6
1911	486	311	797	574	772	1,346	84.4	40.3	59.2
1912	486	344	830	579	793	1,372	83.9	43.4	60.5

During the period from 1903 to 1912, the average number of week day through passenger trains increased 31.6 per cent and the average number of Sunday through passenger trains increased 44.1 per cent. The increase in the total number of through trains arriving and departing was 33.5 per cent and the increase in the number of through passengers was 56.4 per cent. The average number of through passengers carried per train increased from 44.6 in 1903 to 52.4 in 1912, a gain of 17.5 per cent.

The number of week day suburban passenger trains increased 7.9 per cent from 1903 to 1912, that of Sunday suburban trains increased 41.2 per cent and the total number of suburban trains increased 10.0 per cent. The average number of suburban passengers per train increased from 140 in 1903 to 157.5 in 1912, a gain of 12.5 per cent.

The number of through and suburban week day trains increased 16.8 per cent during the ten-year period, while the number of Sunday through and suburban trains increased 42.8 per cent. The total number of passenger trains per year increased 19.0 per cent from 1903 to 1912. The average number of passengers per train arriving and departing was 102 in 1903 and 111 in 1912, the increase being 8.8 per cent.

It may be of interest to note in this connection that the average number of passengers per train for the whole United States was 46 in 1903 and 56 in 1912. This represents an increase of 21.7 per cent.

203.09 Conclusions with Reference to the Increase in the Number of Passenger Trains: The rate of increase in the number of passenger trains is represented graphically by fig. 434.

Superimposed upon the curves of actual growth are approximate curves, the equations for which are as follows:

Through trains:

$$T = 406\,Y^{0.156}$$

Suburban trains:

$$T = 732\,Y^{0.034}$$

Through and suburban trains:

$$T = 1130\,Y^{0.083}$$

"T" represents the number of trains per average week day and "Y" the number of years succeeding 1902, 1903 being year one.

From these equations it appears that, from 1903 to 1912, the number of through trains per average week day increased with the 0.156th power of the number of years succeeding 1903. The number of suburban trains per average week day increased with the 0.034th power of the number of years succeeding 1902. The total number of passenger trains per average week day increased with the 0.083th power of the number of years succeeding 1902. These equations constitute a definition of the law of increase during the ten years ending with 1912. Assuming that the law thus established will hold for the ten years following 1912, it is possible to employ the equations by substituting the appropriate value for "Y" in determining the number of trains for any year subsequent to 1912. The results of such a process are represented by the extended curves as shown in fig. 434, and also by the numerical values presented by table CCXVII.

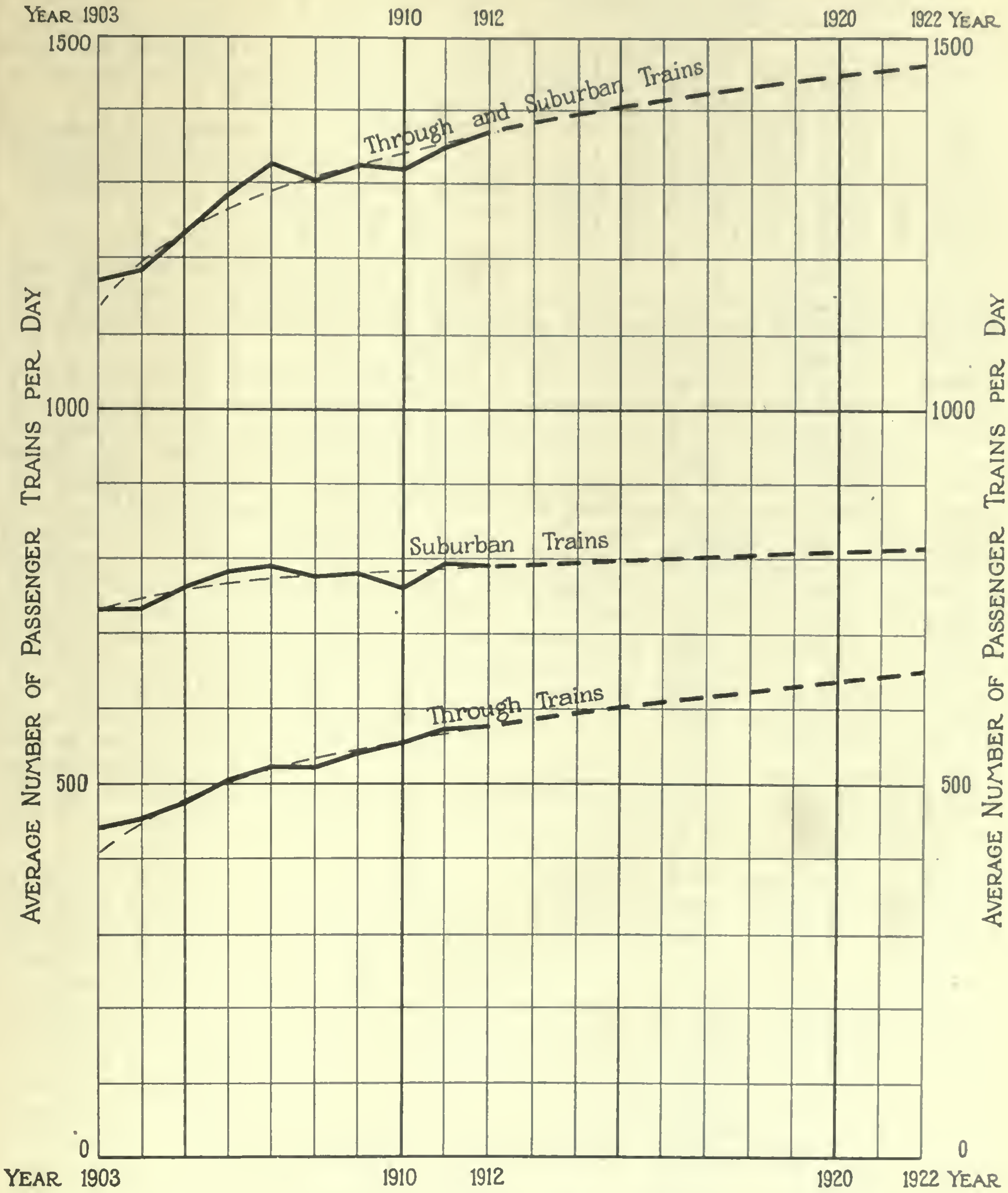


FIG. 434. ANNUAL INCREASE IN THE NUMBER OF PASSENGER TRAINS OF STEAM RAILROADS IN CHICAGO

TABLE CCXVII. ESTIMATED FUTURE INCREASE IN THE AVERAGE NUMBER OF WEEK DAY SCHEDULED PASSENGER TRAINS

Year	Through Trains	Per Cent of Increase over 1912	Suburban Trains	Per Cent of Increase over 1912	Through and Suburban Trains	Per Cent of Increase over 1912
1	2	3	4	5	6	7
1912	579		793		1,372	
1913	589	1.7	795	0.2	1,384	0.9
1914	597	3.1	798	0.6	1,395	1.7
1915	605	4.5	800	0.9	1,405	2.4
1916	613	5.8	802	1.1	1,415	3.2
1917	619	6.9	804	1.4	1,423	3.7
1918	625	7.9	806	1.6	1,431	4.3
1919	631	8.9	808	1.9	1,439	4.8
1920	637	10.0	810	2.1	1,447	5.5
1921	643	11.1	811	2.3	1,454	5.9
1922	650	12.3	812	2.4	1,462	6.7

By the year 1922, the average number of week day through trains will have increased 12.3 per cent over the number of such trains in 1912. Referring to table CCXII, it will be seen, however, that the number of passengers per train will have increased only from 52.4 in 1912 to 58 in 1922, an increase of but 10.5 per cent.

The number of suburban passenger trains arriving and departing on an average week day in 1922 will be 2.4 per cent greater than in 1912. This increase in the number of trains will accommodate the 7.2 per cent increase in the number of suburban passengers, with an increase of 3.5 per cent in the average number of passengers per train.

The average number of week day through and suburban passenger trains in 1922 will be 6.7 per cent greater than that in 1912.

203.10 Freight Traffic: There are 27 railroads which move freight cars in and out of the Chicago terminals, and of these 26 handle freight in less-than-carload lots. In obtaining statistics relating to the movement of freight within the Area of Investigation, information was requested on "Form 28," which is reproduced as fig. 435.

"Form 28" requested the railroads to report all freight received and forwarded through all terminal freight houses within the Area of Investigation. This is what is commonly called the "L. C. L.," or less-than-carload freight, and does not include the tonnage handled at team tracks in carload lots. The results of this inquiry are summarized in tables CCXVIII, CCXIX and CCXX.

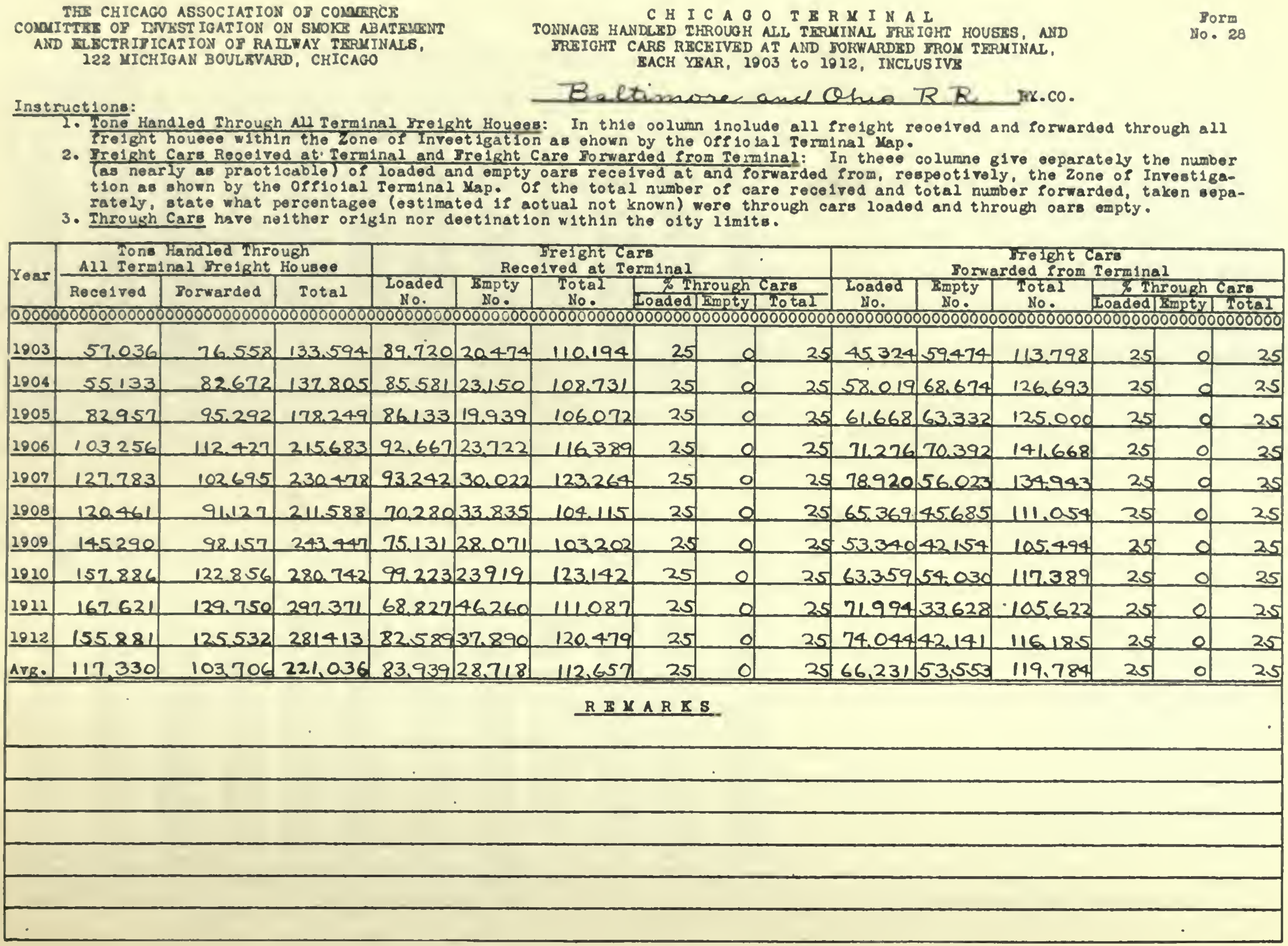
Five railroads made no report. The total tonnage presented by the tables is the total for roads reporting, and it is obviously less than the total for Chicago. The tables present results by years, the increase by roads for the ten-year period from 1903 to 1912, inclusive, the totals for all roads by years and the increase for all roads for the ten-year period.

The number of cars received, the number of cars forwarded and the number of cars received and forwarded are shown by tables CCXXI, CCXXII and CCXXIII.

The total number of cars reported, as shown by these tables, represents the number for the roads reporting. It is obviously less than the total number for all roads since five railroads did not report.

These tables also show the increase in the number of cars for each year of the ten-year period from 1903 to 1912, inclusive, the totals for all railroads by years and the total increase. Information concerning a separate accounting of loaded and empty cars and the percentage of the total represented by through cars, both loaded and empty, could not be given by most of the operating companies, and no attempt has been made to formulate values for these factors. With reference to the values presented in tables CCXXI to CCXXIII, inclusive, the fact should be noted that, in arriving at points within the Area of Investigation, or in leaving it, cars sometimes crossed the boundary twice, in which cases they were so reported. It is possible, therefore, that for some railroads the number of cars operated may be somewhat in excess of the true number of cars received and forwarded by the road.

The limitations which apply to tables CCXXI to CCXXIII, inclusive, are not significant and do not impair their value as a basis upon which to study the growth of the Chicago railroad terminals. The tonnage figures presented, while incomplete, include over 95 per cent of the total tonnage handled through all of the terminal freight houses. It is fair to assume that the rate of increase for 95 per cent of the total freight handled will not differ greatly from the rate of increase for the remaining 5 per cent not recorded. Similarly, regarding the probability of cars being reported twice, the fact remains that, if they were reported in the same manner for all years, the percentage of increase representing growth is reasonably correct.



THE CHICAGO ASSOCIATION OF COMMERCE
COMMITTEE OF INVESTIGATION ON SMOKE ABATEMENT
AND ELECTRIFICATION OF RAILWAY TERMINALS,
122 MICHIGAN BOULEVARD, CHICAGO

CHICAGO TERMINAL
TONNAGE HANDLED THROUGH ALL TERMINAL FREIGHT HOUSES, AND
FREIGHT CARS RECEIVED AT AND FORWARDED FROM TERMINAL,
EACH YEAR, 1903 to 1912, INCLUSIVE

Form
No. 28

Baltimore and Ohio R.R. RY.CO.

Instructions:

1. Tons Handled Through All Terminal Freight Houses: In this column include all freight received and forwarded through all freight houses within the Zone of Investigation as shown by the Official Terminal Map.
2. Freight Cars Received at Terminal and Freight Cars Forwarded from Terminal: In these columns give separately the number (as nearly as practicable) of loaded and empty cars received at and forwarded from, respectively, the Zone of Investigation as shown by the Official Terminal Map. Of the total number of cars received and total number forwarded, taken separately, state what percentages (estimated if actual not known) were through cars loaded and through cars empty.
3. Through Cars have neither origin nor destination within the city limits.

Year	Tons Handled Through All Terminal Freight Houses			Freight Cars Received at Terminal						Freight Cars Forwarded from Terminal					
	Received	Forwarded	Total	Loaded No.	Empty No.	Total No.	% Through Cars			Loaded No.	Empty No.	Total No.	% Through Cars		
							Loaded	Empty	Total				Loaded	Empty	Total
1903	57.036	76.558	133.594	89.720	20.474	110.194	25	0	25	45.324	59.474	113.798	25	0	25
1904	55.133	82.672	137.805	85.581	23.150	108.731	25	0	25	58.019	68.674	126.693	25	0	25
1905	82.957	95.292	178.249	86.133	19.939	106.072	25	0	25	61.668	63.332	125.000	25	0	25
1906	103.256	112.427	215.683	92.667	23.722	116.389	25	0	25	71.276	70.392	141.668	25	0	25
1907	127.783	102.695	230.478	93.242	30.022	123.264	25	0	25	78.920	56.023	134.943	25	0	25
1908	120.461	91.127	211.588	70.280	33.835	104.115	25	0	25	65.369	45.685	111.054	25	0	25
1909	145.290	98.157	243.447	75.131	28.071	103.202	25	0	25	53.340	42.154	105.494	25	0	25
1910	157.886	122.856	280.742	99.223	23.919	123.142	25	0	25	63.359	54.030	117.389	25	0	25
1911	167.621	129.750	297.371	68.827	46.260	111.087	25	0	25	71.994	33.628	105.622	25	0	25
1912	155.881	125.532	281.413	82.589	37.890	120.479	25	0	25	74.044	42.141	116.185	25	0	25
Avg.	117,330	103.706	221,036	83.939	28.718	112.657	25	0	25	66,231	53,553	119.784	25	0	25

REMARKS

FIG. 435. TYPICAL RAILROAD REPORT OF FREIGHT HANDLED ("FORM 28")

TABLE CCXVIII. TONS OF FREIGHT RECEIVED THROUGH FREIGHT HOUSES IN THE CHICAGO TERMINALS

Railroad *	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	Increase from 1903 to 1912	
											Tons	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13
Atchison, Topeka & Santa Fe Ry	25,941	19,118	20.830	27.785	27,633	22,037	21.948	24,992	23,612	22,608	3.333†	12.8†
Baltimore & Ohio R. R.	57.036	55.133	82.957	103.256	127,783	120.461	145,290	157,886	167,621	155.881	98.845	173.0
Baltimore & Ohio Chicago Terminal R. R.	3.960	3,478	2.198	....	....	....	....	....	678	5.357	1,397	35.3
Chesapeake & Ohio Ry. of Indiana	....	....	....	....	....	....	....	14,309	21.536	35,030	20,721‡	145.0‡
Chicago & Eastern Illinois R. R.	39,200	42,300	42.200	48.568	51,918	48.158	61.458	72.177	63,231	65,007	25.807	65.8
Chicago & North Western Ry	160,388	164,305	163.298	209.125	273.195	266.281	291,575	328,203	333.311	359,064	198.676	124.0
Chicago, Burlington & Quincy R. R.	116.500	116.000	132,000	140,086	161,442	93,937	139.126	225.363	171.610	182.416	65.916	56.6
Chicago Great Western R. R.	57.500	58.800	58,500	68.400	74.000	65.700	73,831	87,031	74,621	63,747	6,247	10.9
Chicago, Indianapolis & Louisville Ry	62,883	61.874	72.622	71.615	63,893	59,816	67,093	70.165	76,768	76,122	13.239	21.0
Chicago, Milwaukee & St. Paul Ry	116.000	117,000	135,969	138,356	106,267	131.209	130,357	126.005	136.947	145.081	29.081	25.1
Chicago, Rock Island & Pacific Ry	61.638	67,177	79,744	71,872	74.645	71.574	72,862	83.827	97.094	100.097	38.459	62.5
Elgin, Joliet & Eastern Ry	280,036	283.135	286.190	289,214	292.319	295.368	304.029	332.695	330,511	328.486	48,450	17.3
Illinois Central R. R.	242.000	248.000	250.000	273,000	289.103	258.729	280.492	315.537	281,596	263.860	21.860	9.0
Lake Shore & Michigan Southern Ry. and Chicago, Indiana & Southern R. R.	294.000	384.000	485.000	315,000	363,000	335.000	367.000	414,000	389.000	423.000	129,000	43.8
Michigan Central R. R.	276,101	288.639	284.928	332.440	263.256	238,682	245.304	299.953	289.304	302,639	26.538	9.6
Minneapolis, St. Paul & Sault Ste. Marie Ry	62.000	60,200	55.700	66,551	60.908	48,511	41,816	52.188	45.698	50.420	11,580†	18.7†
New York, Chicago & St. Louis R. R.	75.602	75.377	75.623	80,756	85.021	85,017	105.031	100.082	105.194	82,545	6.943	9.2
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	117.713	115.650	138.773	173.650	169.897	148.573	159.557	171.246	169.542	182,369	64,656	54.8
Pittsburgh, Fort Wayne & Chicago Ry	127.500	142.000	164.000	184.000	196.584	192,766	178.472	183.608	179,206	207,922	80,422	63.1
Wabash R. R.	125,301	142.635	152.062	159,811	173.554	157,591	150.446	145.251	140.397	155,475	30.174	24.1
Totals	2.301.299	2.444,821	2.622.594	2,753.494	2.854,418	2.642.410	2,835.687	3,204.518	3,097,477	3,207.126	905.827	39.4

* Five roads handling freight through freight houses did not report.

† Decrease.

‡ Increase 1910 to 1912.

TABLE CCXIX. TONS OF FREIGHT FORWARDED THROUGH FREIGHT HOUSES IN THE CHICAGO TERMINALS

Railroad *	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	Increase from 1903 to 1912	
											Tons	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13
Atchison, Topeka & Santa Fe Ry	171,264	168,061	187.761	229.119	317.625	282,294	322,454	341.699	327.227	341.243	169.979	99.3
Baltimore & Ohio R. R.	76,558	82.672	95.292	112.427	102.695	91,127	98.157	122,856	129,750	125.532	48.974	63.9
Baltimore & Ohio Chicago Terminal R. R.	49,500	43,375	37,589	97,329	106,244	82,136	97,586	97.189	108,494	135,779	86.279	174.0
Chesapeake & Ohio Ry. of Indiana	....	....	....	....	....	....	....	9,539	14.357	23.353	13.814†	145.0†
Chicago & Eastern Illinois R. R.	132.200	142.900	142.400	164,027	180,238	143.505	169.928	175.173	197,220	200.488	68.288	51.7
Chicago & North Western Ry	639,707	665.097	696,136	743.185	730.607	667.074	768,051	817,700	761,877	853,800	214,093	33.5
Chicago, Burlington & Quincy R. R.	431.000	429,000	489.000	517.358	586.320	510,819	645.593	722.764	676.920	588.647	157.647	36.6
Chicago Great Western R. R.	87.000	88.900	88.500	103,600	112,000	99,300	111.444	131,985	131.869	119.948	32.948	37.9
Chicago, Indianapolis & Louisville Ry	37.497	46,014	54,201	53,332	48,596	48.648	50,614	44.408	55.609	51,926	14.429	38.5
Chicago, Milwaukee & St. Paul Ry	402,000	405.000	470,211	593,289	606.213	604.981	702,702	715.131	732,499	532.276	130.276	32.4
Chicago, Rock Island & Pacific Ry	172.677	171.312	202.050	220,197	226.021	186,392	217,613	224.738	206.007	187,562	14,885	8.6
Elgin, Joliet & Eastern Ry	172.634	174.531	176,428	178.325	180.122	182.129	183.958	188.467	186.225	190.491	17.857	10.3
Illinois Central R. R.	408.000	418,000	422.000	461.000	487,933	464,576	549.736	574.294	468,409	440.932	32,932	8.1
Lake Shore & Michigan Southern Ry. and Chicago, Indiana & Southern R. R.	162.000	178,000	241.000	281,000	375.000	323.000	372,000	403.000	391.000	419.000	257.000	158.5
Michigan Central R. R.	305,281	309,818	290,825	326.382	269.688	263,844	294,188	306.496	319,346	324,678	19.697	6.5
Minneapolis, St. Paul & Sault Ste. Marie Ry	56.800	55.100	51.000	60.945	64,148	60,392	66.760	79.367	80,563	77.517	20.717	36.4
New York, Chicago & St. Louis R. R.	32.400	33,865	39,642	43,843	45.781	43.796	48.739	52.292	38.627	28,813	3,587‡	11.1‡
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	127,935	121.640	138,411	141,314	145.905	127.943	152.298	169.146	165,162	193,838	65.903	51.5
Pittsburgh, Fort Wayne & Chicago Ry	154.500	164,000	191.000	216.000	231,266	198.225	221,081	269,903	240.432	295.070	140,570	90.9
Wabash R. R.	130.009	131.300	141,160	179,972	180.528	156,059	180,674	198,057	199,301	211.611	81,602	62.8
Totals	3,748,962	3.828.585	4,154,606	4,722,644	4,996,930	4,536,250	5,253.576	5,644,204	5,430,804	5,312,504	1,593.542	42.4

* Five roads handling freight through freight houses did not report.

† Increase 1910 to 1912.

‡ Decrease.

TABLE CCXX. TONS OF FREIGHT RECEIVED AND FORWARDED THROUGH FREIGHT HOUSES IN THE CHICAGO TERMINALS

Railroad *	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	Increase from 1903 to 1912	
											Tons	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13
Atchison, Topeka & Santa Fe Ry	197,205	187,179	208,591	256,904	345,258	304,331	344,402	366.691	350,839	363,851	166,646	84.5
Baltimore & Ohio R. R	133,594	137,805	178,249	215,683	230,478	211,588	243,447	280,742	297,371	281,413	147,819	111.0
Baltimore & Ohio Chicago Terminal R. R	53,460	46,853	39,787	97,329	106,244	82,136	97,586	97,189	109,172	141,136	86,676	162.0
Chesapeake & Ohio Ry. of Indiana	....	....	....	....	....	....	....	23,848	35,893	58,383	34,535†	145.0†
Chicago & Eastern Illinois R. R	171,400	185,200	184,600	212,595	232.156	191,663	231,386	247.350	260,451	265,495	94,095	54.8
Chicago & North Western Ry	800,095	829,402	859,434	952,310	1,003,802	933,555	1,059,626	1,145,903	1,095,188	1,212,864	412,769	51.6
Chicago, Burlington & Quincy R. R	547,500	545,000	621,000	657,444	747,762	604,756	784,719	948,127	848,530	771,063	223,563	40.7
Chicago Great Western R. R	144,500	147,700	147,000	172,000	186,000	165,000	185,275	219,016	206,490	183,695	39,195	27.1
Chicago, Indianapolis & Louisville Ry	100,380	107,888	126,823	124,947	112,489	108,464	117,709	114,573	132,377	128,048	27,668	27.6
Chicago, Milwaukee & St. Paul Ry	518,000	522,000	606,180	731,645	712,480	739,190	833,059	841,136	869,446	677,357	159.357	30.8
Chicago, Rock Island & Pacific Ry	234.315	238,489	281,794	292,069	300,666	257,966	290.475	308,565	303,101	287,659	53,344	22.7
Elgin, Joliet & Eastern Ry	452,670	457,666	462.618	467,539	472,441	477,497	487,987	521,162	516,736	518,977	66,307	14.6
Illinois Central R. R	650,000	666,000	672,000	734.000	777,036	723,305	830,228	889.831	750,005	704,792	54.792	8.4
Lake Shore & Michigan Southern Ry. and Chicago. Indiana & Southern R. R.	456,000	562,000	726,000	596,000	738,000	658,000	739,000	817,000	780,000	842,000	386,000	84.7
Michigan Central R. R	581,382	598,457	575,753	658,831	532,944	502,526	539,492	606,449	608,650	627,317	45,935	7.9
Minneapolis, St. Paul & Sault Ste. Marie Ry	118,800	115,300	106.700	127,496	125,056	108,903	108,576	131,555	126,261	127,937	9,137	7.7
New York, Chicago & St. Louis R. R	108,002	109,242	115,265	124,599	130,802	128,813	153,770	152,374	143,821	111,358	3.356	3.1
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	245.648	237,290	277,184	314,964	315,802	276,516	311,855	340.392	334,704	376,207	130,559	53.0
Pittsburgh, Fort Wayne & Chicago Ry	282,000	306,000	355,000	400,000	427,850	390.991	399,553	453.511	419,638	502,992	220.992	78.4
Wabash R. R	255,310	273,935	293,222	339,783	354,082	313,650	331,120	343.308	339,698	367,086	111,776	43.8
Totals	6.050,261	6.273,406	6,835.200	7,475,778	7,851,348	7,378,650	8,089,263	8,828,722	8,528,371	8,549,630	2,499,369	41.3

* Five roads handling freight through freight houses did not report.

† Increase 1910 to 1912.

TABLE CCXXI. NUMBER OF FREIGHT CARS RECEIVED ANNUALLY IN THE CHICAGO TERMINALS

Railroad *	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	Increase from 1903 to 1912	
											Cars	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13
Atchison, Topeka & Santa Fe Ry	62,308	58,613	58,563	59,246	60.477	57,694	62.818	68,361	60,492	65.183	2.875	4.6
Baltimore & Ohio R. R	110,194	108,731	106.072	116,389	123,264	104,115	103,202	123,142	111,087	120.479	10,285	9.4
Baltimore & Ohio Chicago Terminal R. R	1,600	1,474	986	....	....	....	....	....	359	1,175	425†	26.5†
Chesapeake & Ohio Ry. of Indiana	....	....	....	....	....	....	....	16.308	22,424	30.131	13.823‡	84.7‡
Chicago & Eastern Illinois R. R	159,500	172,400	171.700	197,839	213,234	177,018	191,343	221,312	214,251	202,127	42.627	26.7
Chicago & North Western Ry	1,315,400	1,288.300	1,384.100	1,516,800	1,653,700	1,555,600	1,746.700	1,882.500	1,884,400	1,951,100	635,700	47.6
Chicago, Burlington & Quincy R. R	479,500	477,500	544,000	575.000	565,000	457,577	478.402	519.687	476,856	515,663	36,163	7.5
Chicago Great Western R. R	104,400	106,700	106,200	124,000	134,000	119,000	133,813	153,691	128,727	123,747	19.347	18.5
Chicago. Milwaukee & St. Paul Ry	585,000	587.000	682.723	724,059	724,999	710,032	752,384	723.784	714,875	564,072	20,928†	3.6†
Chicago, Indianapolis & Louisville Ry	55,604	61,110	69,896	78,490	70,760	66,462	67,552	67,892	73,768	73,916	18,312	32.9
Chicago, Rock Island & Pacific Ry	127,200	136,260	143,020	136,430	140.450	114,500	121.650	142,500	124.400	144,800	17,600	13.8
Elgin, Joliet & Eastern Ry	120,099	152,701	168,341	213,542	242,236	157,723	510,741	769.722	833,823	1,192,309	1,072,210	893.0
Illinois Central R. R	524,000	536,000	540,000	590,000	625,000	571,000	577,809	550,200	582,737	544,552	20,552	3.9
Indiana Harbor Belt R. R	....	....	....	....	177,548	202,654	268,167	346,613	340.642	395,340	217,792¶	122.5¶
Lake Shore & Michigan Southern Ry. and Chicago. Indiana & Southern R. R.	310.364	330.238	420,853	473,630	482,787	463,115	483,280	514.473	500,584	515.518	205,154	66.1
Michigan Central R. R	146,606	150,020	165,098	186.737	179,466	171,718	175,692	174.069	171.096	171,292	24.686	16.8
Minneapolis, St. Paul & Sault Ste. Marie Ry	6,800	6.600	6,100	7,293	8.267	7,628	8,491	7,794	6,692	7,535	735	10.8
New York, Chicago & St. Louis R. R	59,116	63,065	63,547	82.731	74,810	80,536	87,529	94,678	95.593	94,481	35,365	59.8
Pittsburgh, Cincinnati. Chicago & St. Louis Ry	120,716	120,732	141,704	157,349	150.578	134,306	146,325	200.511	165,549	185,785	65,069	53.8
Pittsburgh, Fort Wayne & Chicago Ry	242.551	243.716	264.804	249,798	281.224	275,846	294.127	321.567	304,060	315.676	73,125	30.1
Wabash R. R	107,478	111,149	115,770	137,231	148,041	141,876	148.201	168,307	157,301	158,722	51,244	47.6
Totals	4.638.436	4,712,309	5,153.477	5,626,564	6,055.841	5,568,400	6,358,226	7.067.111	6,969.716	7,373.603	2,735,167	58.9

* Five roads handling freight cars did not report.

† Decrease.

‡ Increase 1910 to 1912.

¶ Increase 1907 to 1912.

TABLE CCXXII. NUMBER OF FREIGHT CARS FORWARDED ANNUALLY BY THE CHICAGO TERMINALS

Railroad *	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	Increase from 1903 to 1912	
											Cars	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13
Atchison, Topeka & Santa Fe Ry	69.108	61.036	59.984	67.392	67.392	62.551	71.628	78.793	74,721	77,355	8,247	11.9
Baltimore & Ohio R. R.	113.798	126,693	125.000	141.668	134.943	111.054	105.494	117.389	105.622	116.185	2,387	2.1
Baltimore & Ohio Chicago Terminal R. R.	11.000	9.610	7,650	15,161	15.010	12,035	13,034	12.155	13.697	16.446	5.446	49.5
Chesapeake & Ohio Ry. of Indiana	....	....	....	....	....	....	....	16,656	22,047	29.722	13.066†	78.4†
Chicago & Eastern Illinois R. R.	156,600	169.300	168.700	194.314	231.433	179.514	188.358	230,172	219.382	207,390	50.790	32.5
Chicago & North Western Ry	1.314.200	1,288,400	1.382.700	1,517.500	1.659.700	1.553,200	1,751.800	1,885.200	1.880.400	1.918.500	634.300	48.2
Chicago, Burlington & Quincy R. R.	479,500	477.500	544.000	575.000	565.000	457.578	478.403	519,687	476.857	515,663	36.163	7.5
Chicago Great Western R. R.	105.000	107.200	106,800	124.400	131.500	119.500	134.343	157.082	134.271	124.057	19.057	18.1
Chicago, Milwaukee & St. Paul Ry	668,000	673,000	781.884	796.107	791,335	767.187	812,002	825.465	779.102	618.469	49.531‡	7.4‡
Chicago, Indianapolis & Louisville Ry	47.860	55.119	67,066	78,834	71.374	65.810	66,782	71.241	80,910	76.902	29,042	60.6
Chicago, Rock Island & Pacific Ry	144.850	142.820	147,170	143.700	145.900	141.500	139,350	159,400	140.700	163.840	18.990	13.1
Elgin, Joliet & Eastern Ry	129.235	127.700	138.735	209,339	238.455	155.279	498.404	769,557	841.387	1,192.852	1.063,617	822.0
Illinois Central R. R.	525,000	537.000	542.000	592,000	627.000	572.500	579.826	555.429	600,611	553,350	28,350	5.4
Indiana Harbor Belt R. R.	....	....	....	....	194.719	213,209	275.686	380,647	360.464	391,879	197,160¶	101.0¶
Lake Shore & Michigan Southern Ry. and Chicago. Indiana & Southern R. R.	278 608	297.957	410,078	503.173	532.478	480.017	501.077	536,589	521.550	531.007	252,399	90.7
Michigan Central R. R.	131.791	125.544	125.929	167.477	160,642	163.357	156,819	161.330	165.732	162.425	30.634	23.2
Minneapolis, St. Paul & Sault Ste. Marie Ry	15,300	14.900	13.800	16 490	17.154	19.781	11.455	19.629	26.673	21,373	6,073	39.7
New York, Chicago & St. Louis R. R.	56,667	59,441	59.337	77.041	72.494	70.666	78.980	80.473	81.168	81.559	24.892	43.9
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	142.100	141.512	154.739	172.640	172,390	156.177	159.189	205.097	178.875	201,422	59,322	41.7
Pittsburgh, Fort Wayne & Chicago Ry	193.365	209,332	243.578	237.953	255,648	240.384	263.665	304.173	276.117	282,709	89.344	46.2
Wabash R. R.	87,102	88.742	91.157	92,906	118.342	111,731	129.285	143.183	144.072	140.031	52.929	60.8
Totals	4.669.084	4.715.806	5.170.307	5.723.065	6.205.918	5.653.030	6.415.580	7,229.350	7.127.358	7.453.136	2.784.052	59.6

* Five roads handling freight cars did not report. † Increase 1910 to 1912. ‡ Decrease. ¶ Increase 1907 to 1912.

TABLE CCXXIII. NUMBER OF FREIGHT CARS RECEIVED AND FORWARDED ANNUALLY BY THE CHICAGO TERMINALS

Railroad *	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	Increase from 1903 to 1912	
											Cars	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13
Atchison, Topeka & Santa Fe Ry	131.416	119.619	118,547	126.638	127.869	120.245	134,446	147.151	135.213	142,538	11.122	8.5
Baltimore & Ohio R. R.	223.992	235.424	231,072	258.057	258,207	215.169	208.696	240.531	216.709	236.664	12.672	5.7
Baltimore & Ohio Chicago Terminal R. R.	12,600	11.084	8,636	15.161	15.010	12.035	13.034	12.155	14.056	17.621	5.021	39.8
Chesapeake & Ohio Ry. of Indiana	....	....	....	....	....	....	....	32.964	44.471	59.853	26.889†	81.6†
Chicago & Eastern Illinois R. R	316.100	341.700	340.400	392.153	444.667	356,532	379.701	451.484	433.633	409.517	93.417	29.5
Chicago & North Western Ry	2.629.600	2,576,700	2.766,800	3,034,300	3,313.400	3.108.800	3.498.500	3.767,700	3.764,800	3.899.600	1.270.000	48.3
Chicago, Burlington & Quincy R. R.	950.000	955,000	1.088,000	1,150.000	1,130,000	915,155	956.805	1,039.374	953.713	1,031,326	72.326	7.5
Chicago Great Western R. R.	209.400	213.900	213.000	248.400	268.500	238.500	268.156	310.773	262.998	247,804	38,401	18.3
Chicago. Milwaukee & St. Paul Ry	1,253.000	1,260,000	1.464.607	1.520,166	1,516.334	1,477.219	1.564.386	1,549.249	1,493.977	1.182,511	70.459‡	5.6‡
Chicago, Indianapolis & Louisville Ry	103.464	116.229	136.962	157.324	142.134	132,272	134.334	139.136	154.678	150,818	47.354	45.7
Chicago, Rock Island & Pacific Ry	272,050	279,080	290.190	280.130	286,350	256,000	261,000	301.900	265.100	308,640	36.590	13.5
Elgin, Joliet & Eastern Ry	249.334	280,401	307.076	422.881	480,691	313.002	1.009.145	1.539.279	1.675.210	2.385.161	2.135.827	856.0
Illinois Central R. R.	1.049.000	1.073.000	1.082.000	1.182.000	1.252,000	1,143.500	1,157.635	1.105.629	1.183.348	1,097,902	48.902	4.7
Indiana Harbor Belt R. R.	....	....	....	....	372.267	415.863	543.853	727,260	704.106	787,219	414,952¶	11.1¶
Lake Shore & Michigan Southern Ry. and Chicago. Indiana & Southern R.R.	588.972	628.195	830,931	976.803	1.015.265	943.132	984.357	1.051.062	1.025.134	1.016.525	457.553	77.7
Michigan Central R. R.	278,397	275.564	291.027	354.184	340.108	335.075	332,511	335,399	336.828	333.717	55,320	19.9
Minneapolis, St. Paul & Sault Ste. Marie Ry	22,100	21.500	19.900	23.783	25.421	27.409	19.946	27,423	33.365	28.908	6.808	30.8
New York, Chicago & St. Louis R. R.	115,783	122.506	122,884	159.772	147,304	151.202	166.509	175,151	176.761	176.040	60.257	52.0
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	262.816	265.244	296.443	329.989	322.977	290.483	305,514	405.608	344,424	387,207	124.391	47.3
Pittsburgh. Fort Wayne & Chicago Ry	435.916	453.048	508,382	487,751	536.872	516.230	557.792	625.740	580,177	598.385	162.469	37.4
Wabash R. R.	191,580	199,891	206.927	230.137	266.383	253.607	277.486	311.490	301,373	298.753	104.173	53.4
Totals	9,307.520	9.428.115	10.323,784	11,349.629	12,261,759	11.221.430	12.773,806	14,296.461	14,097.074	14.826.739	5,519.219	59.2

* Five roads handling freight cars did not report. † Increase 1910 to 1912. ‡ Decrease. ¶ Increase 1907 to 1012.

FIG. 436. TONNAGE OF FREIGHT HANDLED ANNUALLY THROUGH FREIGHT HOUSES IN THE CHICAGO TERMINALS

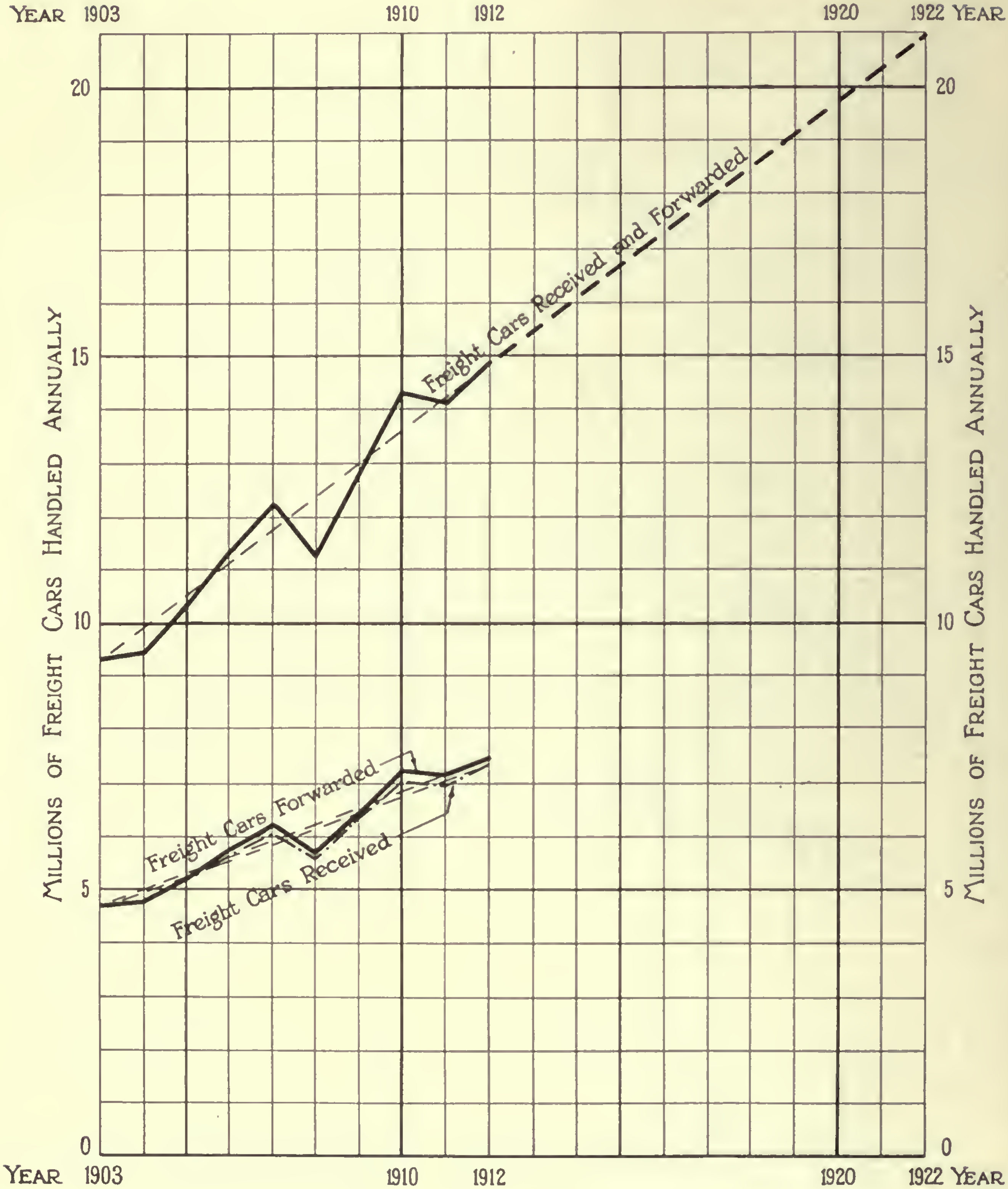


FIG. 437. ANNUAL INCREASE IN THE NUMBER OF FREIGHT CARS RECEIVED AND FORWARDED ANNUALLY BY THE CHICAGO TERMINALS

A few roads were unable to give the required information for all years. In such cases, deficiencies were supplied by estimates obtained by interpolation, supplemented by comparisons based on returns from other roads. As in the case of passenger traffic, methods of making estimates were generally approved by a representative of the railroad concerned. The following statements indicate the extent to which resort to estimates was employed:

Baltimore & Ohio Chicago Terminal R. R.: Number of freight cars and tonnage of freight were estimated for the year 1903.

Chicago & Eastern Illinois R. R.: Number of freight cars and tonnage of freight were estimated for the years 1903 to 1905, inclusive.

Chicago & North Western Ry.: Number of freight cars was estimated by this company for all years.

Chicago, Burlington & Quincy R. R.: Number of tons of freight was estimated for the years 1903, 1904 and 1905. The number of freight cars received and forwarded was estimated for all years; however, the total number of cars for each year was reported.

Chicago Great Western R. R.: The tonnage of freight and the number of freight cars were estimated for the years 1903 to 1908, inclusive.

Chicago, Indianapolis & Louisville Ry.: The tonnage of freight was estimated for the year 1903.

Chicago, Milwaukee & St. Paul Ry.: The tonnage of freight and the number of freight cars received were estimated for the years 1903 and 1904.

Illinois Central R. R.: The tonnage of freight was estimated for the years 1903 to 1906, inclusive, and the number of freight cars was estimated for the years 1903 to 1908, inclusive. The figures include the traffic of the Cleveland, Cincinnati, Chicago & St. Louis Ry.

Lake Shore & Michigan Southern Ry.: The tonnage of freight and the number of freight cars were estimated for all years. The figures include Chicago, Indiana & Southern R. R. freight tonnage and cars which could not be segregated.

Minneapolis, St. Paul & Sault Ste. Marie Ry.: The tonnage of freight and the number of freight cars were estimated for the years 1903 to 1905, inclusive.

Pittsburgh, Fort Wayne & Chicago Ry.: The tonnage of freight was estimated for the years 1903 to 1906, inclusive.

From the statistics reported or estimated and finally recorded in the tables, it appears that the tonnage received through freight houses, as reported for 1912, represented only about 37.5 per cent of that received and forwarded. The amount was 39.4 per cent greater in 1912 than in 1903. The tonnage forwarded through freight houses, as reported for 1912, represented 62.5 per cent of that received and forwarded, and the amount showed an increase of 42.4 per cent over the similar tonnage for 1903. The total tonnage handled was 41.3 per cent greater in 1912 than in 1903. For the same period, the increases in the number of cars received and the number of cars forwarded were respectively 58.9 per cent and 59.6 per cent. The number of cars received and forwarded increased 59.2 per cent during the period.

203.11 Conclusions with Reference to the Increase in Freight Traffic: The number of tons of freight and the increase in tonnage handled through freight houses is shown graphically by fig. 436.

In fig. 436, curves approximating the statistical facts are also shown, and from these the following equations have been derived:

Tons of freight received:

$$T = 1{,}000{,}000\ (2.30 + .101\ [Y-1])$$

Tons of freight forwarded:

$$T = 1{,}000{,}000\ (3.46\ Y^{0.203})$$

Tons of freight received and forwarded:

$$T = 1{,}000{,}000\ (5.50\ Y^{0.205})$$

In these equations "T" represents the number of tons of freight and "Y" the number of years succeeding 1902, the year 1903 being taken as year one.

The equations show that the reported tonnage of freight received in the Chicago terminals increased approximately 101,000 tons per year. The total number of tons of freight forwarded increased as the 0.203th power of the number of years succeeding 1902. The total number of tons of freight received and forwarded increased as the 0.205th power of the number of years succeeding 1902.

Curves approximating the statistical facts with reference to the number of freight cars and the rate of increase in the number of freight cars received and forwarded in the Chicago railroad terminals are presented as fig. 437.

From these curves the following equations have been derived:

Cars received:

$$C = 1{,}000{,}000\ (4.64 + 0.304\ Y)$$

Cars forwarded:

$$C = 1{,}000{,}000\ (4.67 + 0.309\ Y)$$

Cars received and forwarded:

$$C = 1{,}000{,}000\ (9.31 + 0.613\ Y)$$

"C" represents the number of cars and "Y" number of years succeeding 1903, the year 1903 being the year zero, 1904 the year one, and so on. These equations indicate that the annual increase in the number of cars received is 304,000, in the number of cars forwarded 309,000, and in the number of cars received and forwarded 613,000.

The values for freight tonnage and number of freight cars may be assumed to represent the law of increase for the period from 1903 to 1912. If the law for that period may be assumed to apply to the ten-year period subsequent to 1912, estimates of future growth may be obtained by substituting the proper value for "Y" in the equation. Results thus derived are shown graphically by an extension of the curves in figs. 436 and 437, and numerically by table CCXXIV.

TABLE CCXXIV. ESTIMATED FUTURE INCREASE OF FREIGHT TRAFFIC IN THE CHICAGO TERMINALS

Year	Tons of Freight Handled Through Freight Houses	Per Cent of Increase over 1912	Total Number of Freight Cars Received and Forwarded	Per Cent of Increase over 1912
1	2	3	4	5
1912	8,549,630	....	14,826,739	....
1913	8,890,000	4.0	15,440,000	4.2
1914	9,110,000	6.6	16,050,000	8.3
1915	9,280,000	8.5	16,660,000	12.4
1916	9,400,000	9.9	17,270,000	16.5
1917	9,540,000	11.5	17,880,000	20.6
1918	9,690,000	13.4	18,490,000	24.7
1919	9,810,000	14.8	19,100,000	28.8
1920	9,910,000	16.0	19,710,000	32.9
1921	10,050,000	17.5	20,330,000	37.1
1922	10,140,000	18.8	20,950,000	41.3

It will be seen that the rate of increase in the traffic handled through freight houses is less than the rate of increase in the total number of cars handled. In 1922, the total tonnage of freight handled through the terminal freight houses will be 18.8 per cent greater than the tonnage in 1912.

Chicago, as a railroad terminal, is the greatest point of interchange for through freight cars in the United States. The number of cars received and forwarded is dependent upon the general traffic activity of the whole country. As the nation's traffic increases Chicago's interchange will increase. It is assumed that the growth for the period from 1903 to 1912, inclusive, indicates the tendency which will obtain for the near future. The number of freight cars received and forwarded in 1922 will, on this assumption, total approximately 21,000,000, an increase of 41.3 per cent over the number handled in 1912.

203.12 Summary of Conclusions with Reference to the Growth of Chicago's Railroad Terminals: The conclusions to be drawn from the studies which have been made concerning the growth of trackage and traffic of the steam railroads of Chicago in the Area of Investigation may be summarized as follows:

1. The total trackage in 1912 was 3,987.58 miles. It may be expected that the increase will be approximately at the rate of 3 per cent per year. By 1922, the total mileage of track will be 30.8 per cent greater than the total mileage in 1912.

2. The number of through passengers arriving and departing in 1912 was 11,099,783. It may be expected that the increase will be approximately at the rate of 4 per cent per year. By 1922, the number of through passengers will be 40.3 per cent greater than the number of such passengers in 1912.

3. The number of suburban passengers arriving and departing in 1912 was 42,119,593. It may be expected that the average increase will be approximately at the rate of 0.7 per cent per year. By 1922, the number of suburban passengers will be 7.2 per cent greater than the number of such passengers in 1912.

4. The number of all passengers arriving and departing in 1912 was 53,219,376. It may be expected that the average increase will be approximately at the rate of 1.4 per cent per year. By 1922, the total number of passengers will be 14 per cent greater than the total number in 1912.

5. The average number of week day scheduled through passenger trains arriving and departing in 1912 was 579 per day. It may be expected that the average increase will be approximately at the rate of 1.2 per cent per year. By 1922, the total number of through passenger trains will be 12.3 per cent greater than that in 1912.

6. The average number of week day scheduled suburban passenger trains arriving and departing in 1912 was 793 per day. It may be expected that the average increase will be approximately at the rate of 0.24 per cent per year. By 1922, the total number of suburban passenger trains will be 2.4 per cent greater than the number of such trains in 1912.

7. The average number of all week day scheduled passenger trains arriving and departing in 1912 was 1,372 per day. It may be expected that the average increase will

be approximately at the rate of 0.7 per cent per year. By 1922, the total number of all passenger trains will be 6.7 per cent greater than the number of such trains in 1912.

8. The number of tons of freight handled through terminal freight houses, as reported in 1912, was 8,549,630. It may be expected that the increase will be approximately at the rate of 1.9 per cent per year. By 1922, the total tonnage handled through freight houses will be 18.8 per cent greater than the total tonnage in 1912.

9. The number of freight cars received in and forwarded from the Area of Investigation, as reported in 1912, was 14,826,739 It may be expected that the increase will be approximately at the rate of 4.1 per cent per year. By 1922, the total number of freight cars will be 41.3 per cent greater than the total number of such cars in 1912.

204. THE POSSIBILITY OF ELIMINATING THE STEAM LOCOMOTIVE AND OF MEETING ALL OPERATING REQUIREMENTS WITHOUT RESORT TO COMPLETE ELECTRIFICATION

SYNOPSIS: The plan of substituting some other type of self-propelled power unit for the steam locomotive has been a subject much discussed in recent years. This chapter presents descriptions of all self-propelled units which have thus far been developed and describes certain inventions which in their further development seem to give promise of a satisfactory solution of the problem. The conclusion is reached that there is available, at this time, no form of locomotive carrying its own power, other than the steam locomotive, capable of handling the traffic of the Chicago railroad terminals.

204.01 Fundamental Aspects of the Problem: There has been considerable discussion concerning the possibility of handling the traffic of the Chicago terminals by means of some power other than steam, the adoption of which would be less revolutionary and would involve less expense than the complete electrification of the terminals. The Committee has, from the beginning of its work, felt the importance of extending its study into any field of activity which gives promise of useful information, and it has not failed to consider the possibilities of the self-propelled motor car or motor locomotive. In the development of this study, the Committee has sought to measure the utility of any system of mechanism by results already accomplished in service rather than by theories concerning results to be expected from mechanisms as yet undeveloped. The problem of producing a satisfactory motor car or motor locomotive for railroad service involves much more than the choice of a type of mechanism or motive power. It is a matter of detail of design, of reliability in service, of efficiency in operation and of cost of maintenance; and these are matters the significance of which can only be demonstrated by extensive trials under the conditions of actual service.

204.02 Service to be Performed: An estimate of the sufficiency of any type of locomotive for the service of the Chicago terminals must be based upon a clear understanding of the work which is being performed by the steam locomotives now operating in the terminals. A detailed discussion of this question is presented in chapter 202, but a review of the facts which are there set forth may be presented in this connection.

Switching service, including freight transfer service and passenger transfer service, constitutes a large part (59 per cent) of the total locomotive-mileage of the terminals. The essential characteristics of the steam locomotives at present engaged in this service, based upon the Committee's observations and upon reports furnished by the railroads, are presented as table CCXXV.

TABLE CCXXV. ESSENTIAL CHARACTERISTICS OF THE STEAM LOCOMOTIVES NOW ENGAGED IN SWITCHING SERVICE IN THE CHICAGO TERMINALS

Weight on Drivers Pounds	Average Weight on Drivers Pounds	Average Rated Maximum Tractive Effort Pounds	Per Cent of Total No. of Locomotives
1	2	3	4
50,000 to 75,000	66,700	19,880	0.72
75,000 " 100,000	94,700	20,000	12.72
100,000 " 125,000	120,000	23,230	30.47
125,000 " 150,000	138,400	30,140	33.16
150,000 " 175,000	166,700	37,420	11.11
175,000 " 200,000	182,500	40,450	8.24
200,000 " 225,000	203,900	42,850	3.58
Average	135,900	28,790	100.00

The facts presented justify the conclusion that a locomotive of from 500 to 800 horse-power, so designed as to develop the tractive effort permitted by a weight of 100,000 to 150,000 pounds on drivers, should serve for the normal switching purposes. Since all other classes of service involve greater power than this, the switching service presents to the designer of any new type of locomotive favorable conditions so far as power requirements are concerned.

Locomotives engaged in road freight service perform 8 per cent of the total locomotive-mileage in the Chicago terminals. The essential characteristics of the steam locomotives at present engaged in this service and data relating to the work to be performed, based upon the Committee's observations and upon reports furnished by the railroads, are as follows:

Average weight on drivers, pounds	158,672
Maximum weight on drivers, pounds	218,300
Average tractive effort, pounds	35,295
Maximum tractive effort, pounds	51,630
Average schedule speed, mi. per hr.	9.4
Average trailing load, tons	988
Average length of run, miles	2.8

Steam locomotives of recent design are heavier and more powerful than the average locomotive in road freight service as defined above. Taking this fact into account, it is believed that road freight service requires for best results a locomotive weighing 200,000 pounds on drivers and capable of developing 2,000 horse-power.

Locomotives engaged in through passenger service perform 16 per cent of the total locomotive-mileage in the Chicago terminals. Essential characteristics of the steam locomotives at present engaged in this service, and data relating to the work to be performed, based upon the Committee's observations and upon information supplied by the railroads, are as follows:

Average weight on drivers, pounds	125,460
Maximum weight on drivers, pounds	178,500
Average tractive effort, pounds	26,620
Maximum tractive effort, pounds	41,150
Average schedule speed, mi. per hr.	19.6
Average trailing load, tons	350
Average length of run, miles	3.6

Through passenger service requires locomotives as powerful as those used in freight service but of somewhat different proportions. Any passenger locomotive designed to handle the through service in and out of the Chicago terminals should be capable of developing not less than 2,000 horse-power.

Locomotives engaged in suburban passenger service perform 17 per cent of the total locomotive-mileage in the Chicago terminals. Essential characteristics of the steam locomotives at present engaged in this service and data relating to the work to be performed, based upon the Committee's observations and upon information furnished by the railroads, are as follows:

Average weight on drivers, pounds	90,540
Maximum weight on drivers, pounds	154,000
Average tractive effort, pounds	19,030
Maximum tractive effort, pounds	34,000
Average schedule speed, mi. per. hr.	19.0
Average trailing load, tons	167
Average length of run, miles	1.2

Suburban service requires locomotives capable of developing from 600 to 1,000 horse-power.

204.03 Classification of Principal Types of Self-Propelled Units: The principal types of self-propelled cars and self-propelled locomotives, other than those using steam, may be classified as follows:

1. Internal Combustion Motor Type.
   a. Mechanical Drive:
   Internal combustion motor with mechanical transmission including clutch and chain or gear.
   b. Electric Drive:
   1. Electric generator direct connected to internal combustion motor in combination with electric motor or motors connected to driving axle or axles.
   2. Same as No. 1, but in combination with storage batteries carried on car or locomotive.
   c. Compressed Air Drive:
   Internal combustion motor direct connected to air compressor in combination with air motor or motors connected to driving axle or axles.
   d. Hydraulic Drive:
   Internal combustion motor direct connected to variable stroke hydraulic pump in combination with hydraulic motor or motors connected to driving axle or axles.
   e. Direct Connected Motor:
   Diesel engine direct connected to the driving axle.
2. Compressed Air Type.
   Air Storage System.
3. Hot Water Type.
   Hot Water Storage System.
4. Storage Battery Type.
   a. Lead Batteries.
   b. Edison Batteries.

Other types have been proposed, some of which are known to be in process of development.

204.04 Internal Combustion Motor Cars and Locomotives:* The development of the internal combustion engine and the marked success which has attended its use in automobile construction naturally suggest the possibility of its application to railroad service. Some progress has

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*See also "The Internal Combustion Engine, Its Use and Development," by W. R. McKeen, Jr., M.E., E.E., Committee's Bulletin III, Vol. II, August, 1912.

already been made in adapting the gasoline engine to the requirements of light or special railroad service, but the power requirements of heavy railroad service are beyond the present capacity of gasoline-driven units. Before entering upon a description of individual mechanisms, it will be well to consider briefly the difficulties which the problem presents.

Modern railroading is conducted upon such an enormous scale and involves the movement of such heavy loads, that the work can be successfully accomplished only through the application of very large power units. It has been shown that ordinary switching service requires the use of locomotives capable of developing from 500 to 800 horse-power, while through freight and through passenger services require units developing from 1,000 to 2,000 horse-power. If an internal combustion locomotive is to take the place of the modern steam locomotive, it must be capable of developing these high rates of power, or railroad operation must be modified to permit the work to be done by smaller units.

The first difficulty, therefore, which confronts the designer of the internal combustion locomotive is that of developing sufficient power. Difficulties in controlling cylinder temperatures incident to the action of internal combustion engines limit the dimensions of cylinders and consequently the amount of power which can be secured from a cylinder. Any failure to observe the limitations controlling the size of cylinders in gasoline engines introduces operating troubles arising from various sources such as pre-ignition and increased difficulties in lubrication. Consequently, whenever the power requirement is greater than that which can be developed by a single cylinder, it is necessary to multiply cylinders, and large power requirements necessitate the use of many cylinders.

Oil engines of the Diesel type are free from some of the limitations which apply to gasoline driven engines. The fuel supplying these engines is not introduced into the cylinder until it is needed and hence there is no trouble from pre-ignition. While limitations in the amount of power which can be developed by a single cylinder must still be recognized, the limiting values are enormously higher for oil engines than for gasoline engines.

Another difficulty in the application of internal combustion engines to locomotive service arises from the fact that such engines are not self-starting. In automobile service, where comparatively light engines are used, the problem of starting is not in itself a difficult one, but in locomotive service, especially in switching where starts and stops are frequent and where the starting must be accomplished with the full load upon the locomotive, the problem is more serious. Ordinarily an internal combustion locomotive must in some way perform the function of starting and of connecting the rotating engine to the driving axle. The performance of such a function, in the presence of the amount of power required in locomotive service, constitutes a difficult problem, to which the simple mechanisms employed in automobile construction have not been successfully applied.

Rapid progress has been made in recent years in the application of the internal combustion engine to marine service. The gasoline engine of small power is used effectively throughout the world for propelling small water craft. The use in large vessels of high powered oil engines of the Diesel type is now quite commonly understood. Marine service is, however, far more favorable than railroad service to the successful use of the internal combustion engine. The starting load may be materially less, and once started, the engine may continue working at practically constant speed for long periods of time. Movements involving frequent starts and stops are always provided for with difficulty in the design of internal combustion engines. Such movements are required less frequently in the engine of a ship than they are in the engine of a locomotive.

The adoption, for general use in the terminal yards of Chicago, of any type of gasoline or oil-driven locomotive, assuming for the moment such a locomotive to be available, would introduce a new element of danger in operation. Every such locomotive would carry its individual supply of gasoline or oil, and distributing centers from which locomotives could receive supplies would be required. The presence of quantities of inflammable materials in store at locomotive terminals, and the fact that tanks of such materials on locomotives must always be associated with the movement of cars, would introduce an element of hazard.

With this general understanding of the principles involved, it will be of interest to consider with some care just what has been accomplished in the adaptation of the internal combustion engine to railroad service.

Mechanical Drive

The Union Pacific Railroad, in 1901, began to develop a gasoline car for use on lines having light traffic. The following description of this car is abstracted from the report of the Committee on Equipment of the American Electric Railway Engineering Association, October, 1912:

> The original car was 31 feet long and was mounted upon one four-wheel truck. Mounted crosswise on this truck was a vertical gasoline engine connected to the axle through a chain and clutch. This car was the forerunner of the present McKeen motor cars which are now being built of steel in lengths as great as 70 feet and with seating capacities for as many as 105 passengers. The equipment of these cars includes a six-cylinder vertical engine of 200 horse-power mounted crosswise on the truck and driving an auxiliary shaft parallel to and between the axles of the truck. The engine is supplied with a compressed air starting device and is connected with the driving axle of the car through the medium of a friction clutch and a chain drive.

FIG. 438. McKEEN MOTOR CAR

These 34-ton cars are reported to have made speeds of more than 75 miles an hour on level track. It is reported also that in May, 1912, there were 124 McKeen cars in service in the United States, Mexico and Australia. An illustration of a McKeen motor car is presented as fig. 438.

Gasoline motor cars having engines mechanically connected to the driving axles are also made by the Hall-Scott Motor Car Company of San Francisco. A number of these cars are reported to be in successful operation. The arrangement of the mechanism is materially different from that of the McKeen cars, although the essential functions are the same. A six-cylinder gasoline engine is mounted in the forward compartment with its shaft lengthwise the car, and is connected through a suitable clutch with a long transmission shaft which in turn connects, through beveled gears, with the front axle of the rear truck.

These mechanically connected gasoline-driven motor cars are reported as performing efficient service on branch lines. The extent to which these cars could be made serviceable in the work of the Chicago terminals is limited. They are chiefly interesting in connection with the present study because of the possibilities they present for the development of a gasoline locomotive. The manufacturers of these cars have, in fact, outlined a proposal for a locomotive, but thus far neither of the companies mentioned has built a machine possessing sufficient power to perform the service of the modern switching locomotive. While the outlook is not without promise, there is at present no mechanism of the type described which the Chicago railroads could substitute for steam locomotives.

Electric Drive

In the internal combustion type of motor car with electric drive, the essential feature of the connecting mechanism is a system of electric devices consisting of a generator, motors and controlling apparatus. The gasoline engine which constitutes the source of power is direct connected to an electric generator, the general arrangement being such as may be found in any centralized power plant. The axles of the car are driven by motors not essentially different from those of any electric car. The engine-generator and the car motors are connected by suitable controlling and transmitting devices. In operation the engine with its connected generator may be started without load and run continuously at uniform speed. It need not be stopped when the car is stopped. With the engine and generator in constant motion the means are at hand whereby the car may be started and stopped with practically the same degree of ease and certainty as attends the operation of cars receiving power from an outside source. While the presence of generators, motors and control apparatus appears at first sight to be a complicated substitute for a friction clutch, the arrangement possesses certain advantages which, it is assumed, justify the increased cost and complication involved. A statement of the historical development of such cars, as abstracted from a report of the Committee on Equipment of the American Electric Railway Engineering Association, October, 1912, is as follows:

> A gasoline-electric car manufactured in the United States in 1890 by the Patton Motor Car Company was equipped with an 18-horse-power gasoline engine direct connected to a 12-kilowatt generator which supplied current to a single 35-horse-power motor. An auxiliary battery of 150 ampere-hour capacity served to assist the generator during acceleration and to supply current for lighting. The weight of this car was 11 tons. Seven years later the same company built a 16-foot car which weighed 13 tons and was equipped with a 25-horse-power gasoline engine direct connected to a 15-kilowatt 220-volt generator which supplied current to two 35-horse-power motors. An auxiliary battery of 200-ampere-hour capacity was employed. This car was designed for a maximum speed of 40 miles per hour when coupled to an 18-ton trailer.
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> In 1902, the General Electric Company, and also William B. Strang, began to experiment simultaneously with the gasoline-electric car in the United States. The General Electric Company built three cars which differed only in size and method of control. The first car, which closely resembled a standard railroad coach, was 65 feet long, 9 feet 8 inches wide, and was divided into engine, baggage and smoking compartments and main saloon. This car weighed 68 tons and seated 40 passengers. The power plant was a six-cylinder, horizontally opposed, 140-horse-power Woolesley engine and was started by the explosion of a powder cartridge in one of the cylinders. The engine was direct connected to a 600-volt generator, which was excited by a 125-volt chain-driven exciter. Current at variable voltage was supplied to the motors. The second car was all steel, 49 feet long, 8 feet 8 inches wide. It weighed 31 tons and was divided into compartments similar to those of the first car, with a seating capacity for 45 passengers, but unlike the first it was constructed for single-end operation only. The engine was of the eight-cylinder, vertical type, of 200-horse-power capacity, and was direct connected to a 600-volt generator. The third car is typical of all of the recent General Electric designs; it is of steel, 70 feet long, weighing 50 tons, and like the other cars is divided into compartments with a seating capacity for 45 passengers. The engine is an eight-cylinder, 125-horse-power, vertical type, 550 revolutions per minute machine, and is started by compressed air. The engine used in the Strang car was of the six-cylinder vertical type, and only the series-parallel method of control was used. The car had an auxiliary battery of 300-ampere-hour capacity, to assist on the peak loads and to operate the car about terminals when the plant was not running. The essential differences of design between the General Electric and the Strang gasoline-electric cars are apparent in the type of engine used, in the method of control and in the storage battery auxiliary.

FIG. 439. TYPICAL GASOLINE-ELECTRIC CAR BUILT BY THE GENERAL ELECTRIC COMPANY

It is reported that approximately 100 General Electric cars are now in service. A typical gasoline-electric car, built by the General Electric Company, is illustrated by fig. 439.

The gasoline-electric car developed by the French Westinghouse Company has lately been introduced into this country by the Drake Railway Automotrice Company of Chicago. Several of these cars are now in service in the United

States. This car is similar in principle to the General Electric Company type, although the details of construction are somewhat different.

A gasoline-electric locomotive, involving the essential features of the gasoline-electric car, has been built by the General Electric Company. This locomotive is now in daily freight and terminal service between Minneapolis and Northfield, Minn., on the lines of the Minneapolis, St. Paul, Rochester & Dubuque Electric Traction Company, popularly known as the "Dan Patch" line. The power plant consists of two generating units, each being a replica of that used in the standard gasoline-electric motor cars built by the General Electric Company. Each of these units consists of an eight-cylinder, four-cycle gasoline engine direct connected to a 600-volt generator. The engines are started by means of compressed air, but are so equipped that after one unit is in operation the second may be started electrically. An auxiliary unit is provided to furnish current for lighting and to drive an air compressor which furnishes the initial charge of air for starting the first engine. The locomotive is of the double-truck type with four motors, one motor being connected through gears to each of the four axles. The locomotive weighs 114,000 pounds and has a maximum tractive effort of 30,000 pounds. While the service of this locomotive is significant, the machine itself is not sufficiently heavy to withstand the service of the Chicago railroad yards and its power is insufficient for much of the work required there. Its designers have considered the practicability of building a locomotive of double its power by installing, in a single vehicle, four standard power units, which would give 32 cylinders capable of developing approximately 800 horse-power. An illustration of the gasoline-electric locomotive now in service on the "Dan Patch" line is shown as fig. 440.

FIG. 440. GASOLINE-ELECTRIC LOCOMOTIVE OF THE "DAN PATCH" LINE

It is evident that the possibilities of developing a gasoline-electric locomotive of sufficient power to be generally serviceable in the terminal work of Chicago have not yet been exhausted.

Compressed Air Drive

In this type, the connection between the axle of the internal combustion engine and the axle of the car is secured through a train of mechanism in which compressed air is the working medium.

A locomotive using compressed air for power has been patented recently by a firm in Glasgow, Scotland. The locomotive carries its own compressing plant, the compressor being driven by Diesel oil engines generating 1,000 horse-power. The design comprises a 14-wheel locomotive, without tender, so arranged as to run with equal facility and at equal speed in either direction. Two sets of oil engines with compressors are located near the center of the locomotive housing. While running, the locomotive will draw its compressed air supply direct from this compressing plant, but power for starting will be taken from a number of bottle-shaped reservoirs placed along the roof. No information is at hand as to progress made in developing a machine under this patent.

A locomotive has been designed and patented by Charles Whiting Baker of New York City, in which compressed air is used to transmit the power of an internal combustion engine to the locomotive axles. This locomotive closely resembles the present steam locomotive. Its cylinders and running gear are similar to those of the steam locomotive except that they are designed for the use of compressed air instead of steam. In place of the boiler there is a cylindrical tank for a charge of compressed air. The supply of compressed air is maintained through the operation of an internal combustion engine of the Diesel type, which drives air compressing cylinders placed directly below the power cylinders of the engine and in tandem with them, the engine piston and the compressor piston being on the same rod. The engine-compressor is designed to run at high speed. The air is stored at comparatively low pressure and before being used is reheated by the exhaust gases from the engine. A system for cooling the engine cylinders is applied, which embodies the principle of bringing the water in direct contact with the lower side of the engine piston, in the space between the engine and air pistons, the steam generated from the cooling water being allowed to pass into the air storage tanks. The design presents many novel and interesting features. No locomotive has as yet been constructed under the Baker patents.

Hydraulic Drive

In this type, the connection between the internal combustion engine shaft and the axle of the car is secured through a mechanism in which a liquid is the working medium. Several similar systems of mechanism have been well worked out and are in use. One of these, the invention of Charles M. Manly of New York City, has been successfully applied to motor trucks.* It consists of a pump attached to the driving shaft of the engine and a fluid-pressure motor on the driving axle or axles of the vehicle in hydraulic connection with the pump. The pump and motor are combined in a single mechanism. The contact is controlled by a single operating lever. The fluid used is oil. With this device the engine may be started without load and run at a constant speed. When the operating lever is moved to one of its extreme positions, the driven shaft revolves in the same direction as the driving shaft and at its highest speed. When the lever is moved to reverse position, the driven shaft revolves in the opposite direction at its highest speed. When the lever occupies a central position, the driven shaft comes to rest. When it is gradually moved from either extreme position towards the center, the speed is gradually reduced from maximum to zero. As the speed of the wheels cannot run ahead of that which corresponds to the position of the lever except as the speed of the engine may be accelerated, the controlling lever serves as a brake. Furthermore, as the speed of the driven shaft decreases the torque increases in like proportion. So far as is known, no application of this device has been made in locomotive construction, but its success as a piece of mechanism suggests the possibility of its being used in such service.

Direct Connected Motor (The Diesel Oil Locomotive)

Thus far the discussion of the progress that has been made in the development of the internal combustion railroad car and locomotive has centered chiefly in the use of the gasoline engine as a source of power. It has been shown that the use of such engines makes difficult the development of large power units such as are required in locomotive service. It has been shown also that, except for the limitation of power, the problem of development centers in the mechanism by which the power of the engine is transmitted to the wheels of the vehicle. To these difficulties, inherent in the design of the gasoline car or locomotive, is to be added that of fuel cost. The locomotive service of the country is an important fuel consuming industry, involving the consumption of approximately a hundred million tons of

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*See "Hydraulic Speed Control," by Charles M. Manly, reprinted from a paper before the Automobile Club of America, Jan. 9, 1912. Also, "Variable Speed Power Transmission," by George H. Barrus and Charles M. Manly, reprinted from the Journal of the American Society of Mechanical Engineers. Archives of the Committee, Vol. C 1.

coal per year. Any change in practice, which would result in transferring even a comparatively small fraction of this service from coal to gasoline, would be likely to affect the price of that fuel.

In turning from the gasoline engine to the crude oil engine of the Diesel type, two of these sources of difficulty are greatly simplified, if they are not wholly overcome. In the Diesel engine the power which can be developed from a single cylinder is raised to limits which satisfy the requirements of locomotive service, and the availability of an abundant fuel supply at low cost is made certain. There remain only those problems of design which center in the engine itself and in the means to be employed in transmitting its power to the wheels of the locomotive. Reference has already been made to the design of Charles Whiting Baker which involves the use of a Diesel engine as its source of power. Attention may now be given to work which was started and carried well on toward its present state of development under the personal direction of the late Dr. Rudolph Diesel.

The Diesel engine,* as a source of power for stationary work, for marine service and as proposed for locomotive service, constitutes a significant factor in the development of the internal combustion locomotive. The principles underlying its design, the variety of uses which it has been made to serve and the extent to which it is used, are all well set forth in a formal address delivered by Dr. Diesel at a meeting of the American Society of Mechanical Engineers at New York, in April, 1912. In this address he described his locomotive (see figs. 441 and 442) in the following terms:

> "Of the Diesel locomotive nothing has heretofore been published. From the early days of my invention, I have been of the opinion that the special features of the Diesel engine would be of even greater importance for transport purposes than for stationary work, and for that reason I have devoted much time to the development of the engine as motive power for transportation mediums. I have already mentioned that I made the first small ship engine in 1902 and that since that time the Diesel marine engine has been developed without interruption. I further mentioned that I made the first automobile engine for trucks in the year 1899, and I looked forward to the development of this branch within a few years. Finally, I have to say that I have worked for five years, together with Sulzer Brothers at Winterthur, and Mr. Adolph Klose of Berlin, on the construction of a Diesel locomotive, and that the first express train locomotive of 1,000 to 1,200 horse-power was finished a few weeks ago and is now on the testing bed in the Winterthur shops. Five years is a very long time, and to explain why the work has taken so long I must mention that the thermo locomotive is the most difficult problem of construction that can be taken up in the way of modern engine building, not only on account of the difficulties in starting and manœuvering with this special kind of motor, but also on account of the limitation in space and weight. Compared with this, the development of the reversing and of the Diesel ship engine has been relatively simple. Fig. 441 shows the design of this locomotive, the car of which was made in the locomotive works of A. Borsig at Berlin. It is 16.6 meters (54.5 feet) long over the buffers and has two buggies of two axles each (1–1), and two driving wheels (2–2). The latter are not directly coupled with the engine but indirectly with the blind axle (3), which is in the meantime the crankshaft of the Diesel engine (4).
>
> "The Diesel engine is an ordinary two-stroke cycle engine with four cylinders (4–4) coupled in pairs under an angle of 90 degrees, and which drives the blind axle (3), cranks of which form an angle of 180 degrees. This disposition gives complete balancing of the moving masses, the first and most important condition when putting such engines on a movable platform. Between the working cylinders are placed two scavenging pumps (5) driven by levers from the connecting rod. Beyond the engine in the roof of the car is placed the muffler (6). On the right of the main engine stands an auxiliary engine (7). This latter consists of two vertical two-stroke cylinders (7–7) coupled to horizontal air pumps (8–8) driven by these cylinders. The cooler for the air compressed by these pumps is indicated at (9). These air pumps serve, according to a special and patented process, to increase the power of the main engine when starting, manœuvering and going uphill, in such a way that auxiliary compressed air and auxiliary oil fuel are conducted into the main cylinders, by which means the diagram is enlarged, making the engine as elastic as a steam engine. For the current running of the locomotive the main cylinders work like ordinary Diesel engines without the help of the auxiliary. To the right of the main engine is placed a battery of air cylinders (10) which help the action of the auxiliary engine and which can be refilled by the auxiliary engine at times when the latter is not used. Two pumps (11 and 12) provide for the water circulation in the cylinder jackets. Apparatus for the back cooling of the water by evaporation is indicated at (13), and at (14) the tanks for fresh water and for fuel. A small donkey boiler at (15) is for the heating of the trains. The channels (16) under the roof lead the fresh air to the suction

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*Invented and developed by Dr. Rudolph Diesel of Munich, Germany.

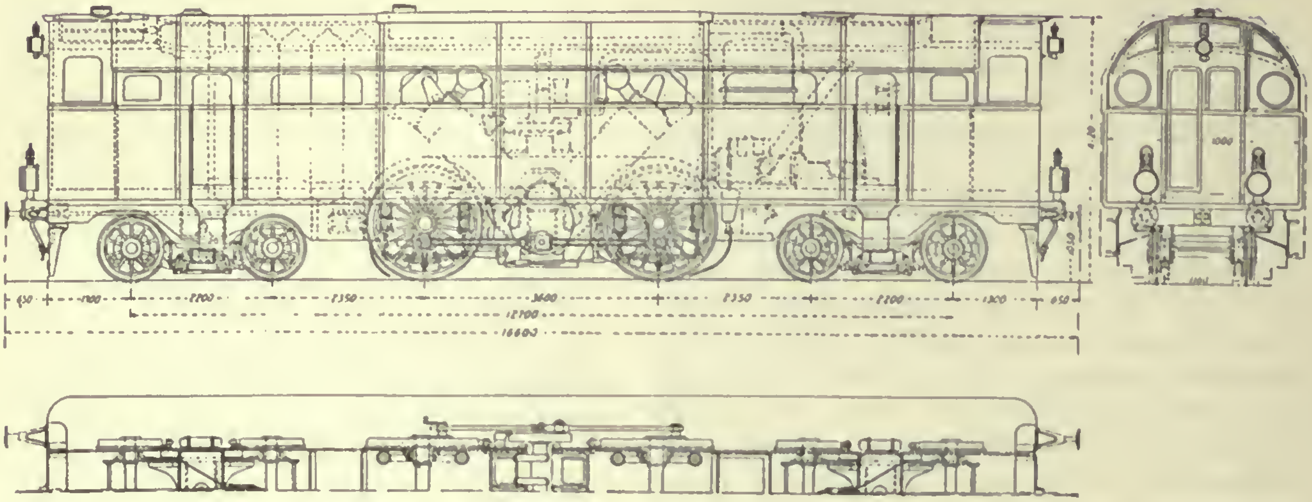

FIG. 441. PRINCIPAL DIMENSIONS OF THE DIESEL LOCOMOTIVE

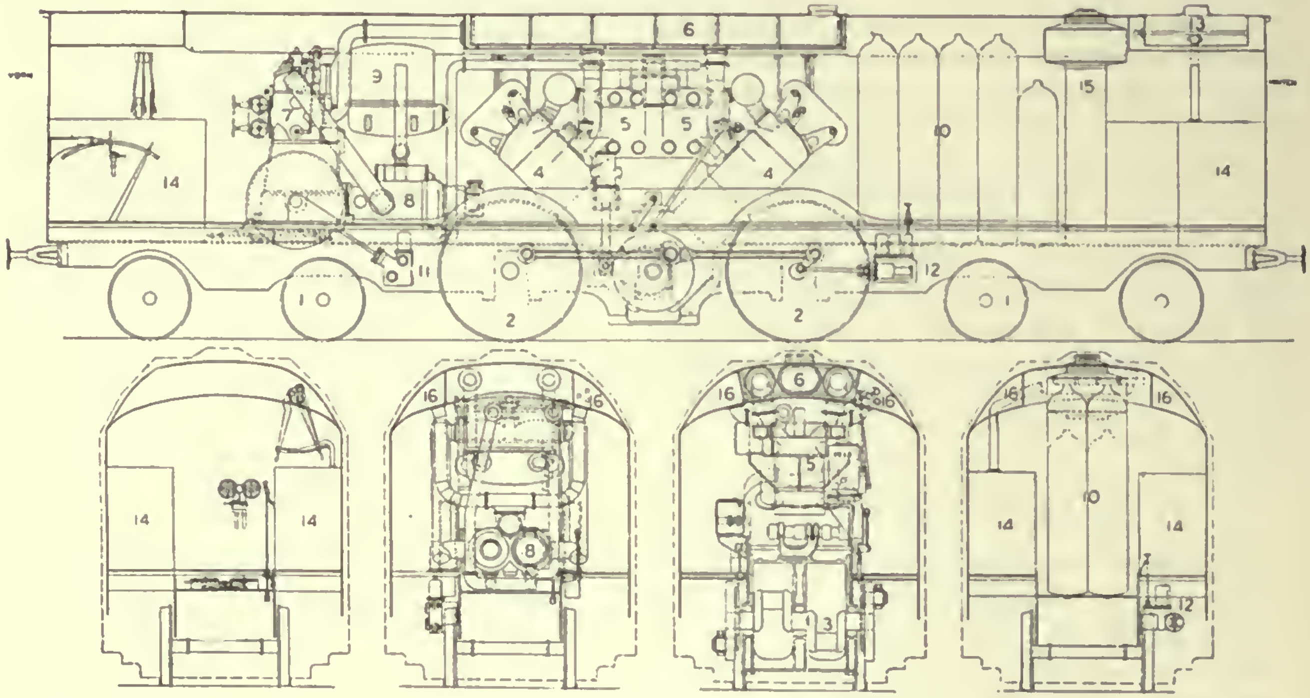

FIG. 442. THE DIESEL LOCOMOTIVE

pipes of the different motors and pump cylinders. The whole plant is contained in a closed engine room, which makes the locomotive look from the exterior like a modern steel car. The total weight of the locomotive in service is 85 tons.

"The engineer can operate equally well on either end of the locomotive, as the engine is arranged for running in both directions. He has a direct view of the track. Both doors and platform lead from the engine to the train.

"I cannot predict whether this attempt at an entire revolution in the working of railways will be successful at the first attempt, or whether it must be repeated, but one thing is certain to me, the Diesel locomotive will come, sooner or later, according to the perseverance with which the problem is followed."

It will be noted from the preceding description that the engine of the Diesel locomotive, being direct connected with the driving mechanism of the vehicle, can be started only as the whole machine proceeds. Starting is accomplished by the use of stored air, the supply of which must be sufficient not merely to spin the engine but to make the locomotive and its attached train proceed. With frequent starting, as in switching service, the engine would have little opportunity to function as an internal combustion engine, for when starting it must act as an air-driven engine.

Dr. Diesel's visit to this country permitted conferences with representatives of the Committee concerning the possibility of the Diesel locomotive for the work of the Chicago terminals. Later, Mr. George Gibbs of the firm of Gibbs & Hill, Consulting Electrical Engineers, made a personal inspection of the experimental Diesel locomotive at the Sulzer Works in Switzerland, as a representative of the Committee. An extract of Mr. Gibbs' report, which describes the results of his investigations, is as follows:

"In accordance with your request, I made, while abroad this summer (1912), such investigation as was practicable of the status of the internal combustion engine of the Diesel type. I called upon Dr. Diesel at Munich and had quite a long talk with him and obtained a letter of introduction to the Sulzer Brothers, builders of his engine in Winterthur, Switzerland. This firm is well known and enjoys an excellent reputation as designers and builders of high class steam engines. They have works in Germany, as well as in Switzerland, but the growth of the Diesel engine as a prime mover has been so great recently that the Sulzers are now devoting their Winterthur factory exclusively to building Diesel engines.

"Diesel Locomotive: I first discussed with Dr. Diesel the question of the adaptation of his engine to locomotive purposes, following the lines of the talk we had with him last spring in New York when Mr. Vauclain, of the Baldwin Locomotive Works, and ourselves, laid down certain requirements of capacity for the Chicago conditions. You will remember that Dr. Diesel was then not very sanguine about meeting the requirements of such heavy service, but said he would look into the question upon his return to Germany. I could not find, however, that he had given the matter further thought; in fact, he appeared to regard the locomotive question as an interesting experiment only and of very minor importance to him compared with other uses for his engine—notably for marine work. He had not himself followed up in detail the tests which were being made with his locomotive, but expressed the opinion that they had been quite successful; sufficiently so to enable him to predict that they could do much better in a future design.

"Dr. Diesel appeared to be doubtful of the success of his engine if it was required mainly for yard switching work, and had directed his efforts wholly toward producing a locomotive for main line express service, as he considered this the logical field for its successful use. He said that the problem of constructing a practical internal combustion locomotive was the most difficult one which could be taken up in the way of engine building, because of the limitations of weight and space, and the difficulties of starting and of speed control. Therefore, the probable field for its use was what we in America might consider light express train service, where constant speed and infrequent stops were the characteristics.

"I afterwards made a special trip to Winterthur to see the experimental locomotive recently completed at the Sulzer Works. I found the factory large and modern, and employing about 4,000 men. They had under construction a large number of Diesel engines for a variety of stationary purposes, generally for small powers, say up to 100 horse-power, and designed for such purposes as pumping in mines, running small factories, etc. A large portion of the plant was devoted to turning out marine engines, especially for torpedo boats and submarines. They had under contract engines for two submarines for the United States Navy, and I saw one of these engines under test.

"In order to determine the maximum power which could be successfully developed in one cylinder of a Diesel engine, they had nearly completed a massive single-cylinder vertical engine of the double-acting, two-stroke cycle type, designed to give 2,000 horse-power. In conversation with their engineer, he expressed an opinion that it would be successful, but that 2,000 horse-power was about the maximum for a single cylinder, because of the enormous pressures developed and the difficulty of cooling.

"I then inspected the Diesel locomotive, which they had tried during the week before in a preliminary way on short runs on a piece of track near the works. At the time, I saw the locomotive, its engine was partly dismantled to make some changes in the valves; but with the exception of valve adjustment, the engineer said the tests had been entirely satisfactory and that they had obtained a speed of 100 kilometers (62 miles) per hour, without, however, pulling a train.

"The locomotive, the design of which you are familiar with from the drawings given in Dr. Diesel's address at the meeting of the American Society of Mechanical Engineers on April 30, 1912, is a very creditable piece of work for the first attempt. From the outside, it looks quite like an electric locomotive, the apparatus being entirely housed in a steel car of neat appearance. Its design and construction have been proceeded with in what we would consider a somewhat leisurely manner, as they have been at work upon it for about five years; the frames and cab were built at the Borsig Locomotive Works in Berlin, and the engines built and the assembly of apparatus done at the Sulzer Works. The general design and dimensions are as follows:

Total length of buffers	54	feet	5⅛	inches
Total wheel base	41	"	8	"
Driving wheel base	11	"	9¾	"
Truck wheel base	7	"	2¼	"
Height, rail to top of cab	13	"	6⅛	"
Width of cab	9	"	10	"
Diameter of drivers	5	"	6	"
Weight	85 tons			

"The engines are four in number, mounted in pairs at an angle of 90 degrees on the locomotive frames. They are of the two-stroke cycle type, and are said to have a capacity of 1,000 horsepower total at 60 miles per hour. The engines drive a jack-shaft axle, with cranks at 180 degrees, set between and in the plane of the driving axles, and power is transmitted to the latter by rods in the usual manner. By this arrangement the balancing of moving parts is complete and should result in smooth running of the locomotive. As the Diesel engine is not self-starting as a combustion engine, compressed air must be used in starting and until the engine has reached a certain speed—in this case about 10 miles per hour, equivalent to about 60 revolutions per minute of the engines. For the above purpose, air is compressed by powerful auxiliary engines coupled to air pumps. These engines are two vertical, two-stroke cycle, Diesel cylinders coupled to horizontal air cylinders compressing to 1,500 pounds per square inch and delivering into a battery of ten large storage cylinders, or tanks, in the cab. Air coolers are also provided. From these tanks air is drawn through reducing valves and used for starting and manœuvering at slow speeds and to deliver auxiliary compressed air with auxiliary oil fuel into the locomotive cylinders.

"In addition, the main engines drive scavenging pumps, compressing air to 1,000 pounds per square inch, for clearing the products of combustion from the cylinders during the running cycles. Pumps are also provided for circulating cooling water, and radiators for air cooling of this water. Water and fuel tanks and a donkey boiler for heating the train are included in the cab apparatus. The locomotive is controlled at either end by a somewhat complicated assemblage of starting and reversing levers and valves, as the engineman must separately control the functions of compressed air and fuel to the cylinders. Viewed as a whole, the interior of the cab is well arranged to house the large amount of apparatus, all of which is reasonably accessible for inspection. The workmanship throughout is first-class—as is essential for success.

"The engineer of the company, in charge of the experiments, was of the opinion that the locomotive would perform well in high speed light service, but did not, with present knowledge, think well of the type for variable work, such as in switching trains. He also hazarded the opinion that a Diesel electric locomotive might be the final development.

"My own general impression may be briefly expressed by saying that the whole matter is in an early experimental stage, with practically no hope that it will be developed to a point where its proper characteristics or field of application will be demonstrated by trial at the time when our Chicago report is made. The best, therefore, that we can do is to express practical opinion upon theoretical premises. In such case, I should say that it appears quite possible that the type can be developed to give satisfactory and probably economical fuel cost results in light express train service with infrequent stops. Its final economy in such service will probably largely depend upon the question of first cost, which I anticipate will be very high as compared with that of steam locomotives of the same capacity. Successful operation will also, of course, depend upon the results of actual tests to demonstrate the running economy, reliability, flexibility and cost of upkeep, all of which factors are unknown at present. The type certainly involves complicated mechanism, and all workmanship must be the finest obtainable. Furthermore, the manipulation of the machine will require considerable skill at all times.

"As the largest part of our service involves the conditions of switching and transfer work at low speeds, all of the above factors become especially important because of the complicated devices required, the delicacy of the mechanism and the rough handling it is necessarily subjected to.

"Another point should be kept in mind; while the internal combustion engine is smokeless under normal running conditions and with proper handling, it is not so when overloaded or when badly adjusted and out of order—especially in starting and in variable working."

204.05 New Types of Mechanism Proposed as a Basis for Locomotive Design: Closely related to the various forms of internal combustion cars and locomotives are several proposed designs for locomotives presenting new combinations of mechanism, the actions of which constitute in effect new cycles of operation. The Heckert locomotive, proposed by Mr. Herman Ray of Chicago, is of this type. It embodies a boiler, a steam-gas engine and a gas producer in a combination presenting theoretical possibilities which, however, have not yet been thoroughly developed either in design or in construction. All such proposals, so far as they affect the practical question of operating the railroad terminals of Chicago, must be regarded as problematical.

204.06 Compressed Air Storage Cars and Locomotives: Compressed air has long been used, under certain prescribed conditions, as a source of power for moving cars and trains of cars. A description of some of the developments with compressed air is given in the following abstract of the report of the Committee on Equipment of the American Electric Railway Engineering Association, October, 1912.

> An application of compressed air to motor cars was made on the Second Avenue Railway, New York, in 1879. The equipment for the service was built in accordance with the Hardie system, in which air was stored at 2,500 pounds pressure and supplied through a reducing valve, at from 300 to 400 pounds pressure, to the engine, which was direct connected to the car driving wheels. In 1896 two Hardie cars were installed on the 125th Street line in New York. This system was a modification of the earlier one, inasmuch as the air was passed through a reducing valve, then through an auxiliary valve at motor pressure and reheated before being admitted to the engine cylinders. The reheating was done to obtain, if possible, an isothermal expansion which would increase the efficiency.
>
> In the year 1891 the Mekarski system had been developed on the Nantes and Paris line in France to such an extent that 26 cars were ordered. In this system the air was stored at 600 pounds pressure and supplied directly to the motors on the basis of isothermal expansion. The cars were designed to run at 8.5 miles per hour. In 1892, the same system was applied to cars in Berne, Switzerland, except that the air was stored and used at 440 pounds pressure.
>
> Meanwhile, similar work was being undertaken in the United States. In 1891 the Toledo Consolidated Street Railway conducted several experiments involving the use of cars driven by compressed air. The use of compressed air for locomotion increased particularly in locations where fire and sparks of any kind were dangerous, as in mines and in and about factories.
>
> In 1897 a Hoadley-Knight car was placed in service on the Twenty-eighth and Twenty-ninth Street line, New York, where it was used for two years. This system had a compound engine, the high pressure cylinders being connected to one axle and the low pressure cylinders to the other. The air was stored at 2,400 pounds pressure and delivered to the motors at 320 pounds pressure. The car weighed 18,750 pounds. About the same time the Metropolitan Street Railway, New York, tried the Hoadley-Knight system on its Lenox Avenue line, with the result that in 1899 twenty cars were installed on the Twenty-eighth and Twenty-ninth Street crosstown line. In 1900, all Hoadley-Knight cars were replaced by Hardie cars. Three of the 1896 type Hardie motor cars were taken to Chicago, where they were used for five years. The Rome (N. Y.) City Railway also used Hardie motors in 1901.
>
> Compressed air cars are heavy, and their bulk is necessarily large in order to provide sufficient space for the storage of air. They are commonly charged at fixed air compressing stations. The efficiency of compression at the station and of expansion in the motors is low; the pressure of the stored air is high and difficult to maintain against leakage. The radius of action with one charge is limited, and if a considerable area is to be served compressor stations must be multiplied. As the problem has developed, the compressed air locomotive is rarely used except to meet the requirements of special services, such as the services in gaseous mines, in chemical factories, and in the yards and buildings of establishments where inflammable materials are handled, the presence of which makes the use of steam locomotives objectionable or dangerous.

It will be seen that compressed air locomotives, in the forms so far developed, can be serviceable only to a very limited extent upon the railroads of the Chicago terminal.

204.07 Hot Water Storage Cars and Locomotives: These have been used to a limited extent for service similar in character to that in which compressed air storage has been employed. Locomotives of this type differ from the normal steam locomotive chiefly in the fact that a large cylindrical receiver is substituted for the boiler and fire-box of the normal locomotive. This receiver is charged from stationary boilers, to about two-thirds of its capacity, with water at high pressure and high temperature. The heat of the water thus stored becomes a source of power for the locomotive. Steam is drawn from the top of the receiver for use in the engine cylinder, the heat of the water serving to keep up the supply at a constantly diminishing pressure, until the temperature of the stored water is so far reduced that the steam pressure corresponding thereto is insufficient for satisfactory operation. Recharging is accomplished by injecting high temperature steam into the water until raised to a condition of pressure and temperature which is the maximum for which the equipment is designed. Locomotives of this type have been of comparatively small power capacity.

204.08 Storage Battery Cars and Locomotives: A description of experiments with storage battery cars and locomotives is given in the following abstract of the report of the Committee on Equipment of the American Electric Railway Engineering Association, October, 1912.

> A locomotive with the Fauré accumulator or storage battery was used at Brueil, France, in 1880. The first storage battery car of this type appeared in 1885. This car weighed only 2.5 tons. Experiments in the use of small storage battery cars were made in Brussels, Belgium, in 1880. In 1889, ten storage battery cars equipped with Julien cells were put in service on the Madison Avenue line in New York City. Later the use of these cars was abandoned.
>
> Experiments with storage batteries were made in Birmingham, England, and a statement issued in 1897 showed operating expenses at 41 cents per car-mile as against receipts of 31.4 cents per car-mile. A storage battery line in Hanover, Germany, was operated during the same year. In 1905, the Prussian-Hessian State Railroads put into service 27 twin-body cars, each seating 100 people, and these were used for light traffic wherever electric energy could be purchased at low cost. The Prussian equipment, in 1908, was increased by 57 cars, each weighing 33.5 tons and seating 70 passengers. During the same year, 19 additional cars were introduced on four lines as feeders to the main line. These cars were equipped with two 50-horse-power series interpole motors, operated from a 368-ampere-hour battery placed under the seats. Later some old passenger coaches were converted into storage battery cars. In 1909, the Prussian road ordered 33 new cars, each 34 feet long and weighing 66 tons. These cars were designed for a maximum speed of 31 miles per hour and a maximum acceleration of 0.56 miles per hour per second. The equipment included a 368-ampere-hour battery and two 80-horse-power motors.
>
> The Englewood & Chicago Railroad built a twelve-mile line between Blue Island and Chicago in 1897, and used 20 storage battery cars each 30 feet long, with a seating capacity for 28 passengers. These cars weighed 13.5 tons each. The equipment included two 50-horse-power motors and chlorid accumulators suspended beneath the car.
>
> An impetus was given to the storage battery motor car industry by the invention and development of the Edison battery. This battery is of the alkaline electrolyte type, with iron and nickel for electrodes. The first Edison-Beach car equipped with these batteries was put in service in 1910 on the Twenty-eighth and Twenty-ninth Street crosstown line in New York, but was removed when the Third Avenue Railroad made an agreement to operate that property with its own storage battery cars.

The first Edison-Beach storage battery car made for a steam road was delivered by the Federal Storage Battery Car Company to the Long Island Railroad Company on April 1, 1911. It was used on a two-mile branch line of this road and is said to have made 38,000 miles previous to October 1, 1912. This car was of the single-truck type. The first double-truck car of this type was placed in regular service on June 28, 1911, on the Lewisburg, Milton and Watsontown Passenger Railroad, a leased line, 11 miles long, owned by the Pennsylvania Railroad Company. It was 40 feet long and seated 40 passengers. Many of these cars are in service in the United States at the present time. The United Railways of Havana recently purchased a three-car storage battery train equipped with Edison-Beach batteries and multiple-unit control system. Each car is 38 feet long and has 220 Edison cells. The motive power for each car consists of four 10-horse-power, 200-volt, 37.5-ampere motors. An illustration of the storage battery car built by the Railway Storage Battery Car Company, the successor to the Federal Storage Battery Car Company, is presented as fig. 443.

In the design of storage battery cars, it has been found desirable to conserve energy by keeping the load to be handled as small as possible and by reducing all frictional losses to the lowest limits. The weight per passenger carried, of several types of cars, is as follows:*

	POUNDS
Pullman car	3,000
Steam day coach	1,500
Steam suburban coach	1,100
Single-truck trolley car	800
Double-truck trolley car	1,000
Double-truck Edison-Beach car	600
Single-truck Edison-Beach car	380

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* Report of the Committee on Equipment of the American Electric Railway Engineering Association, October, 1912.

FIG. 443. STORAGE BATTERY CAR BUILT BY THE RAILWAY STORAGE BATTERY CAR COMPANY

The possibility of utilizing storage battery locomotives in yard switching and other terminal work has made a strong appeal to those interested in the operation of the Chicago railroad terminals. The investigations of the Committee have included voluminous correspondence and various interviews with those who are concerned in the development of the art in this country. It appears that thus far the application of the storage battery to cars has involved very light construction. Storage battery locomotives have all been comparatively small, and suitable for use only in mines, or in other industrial or highly specialized service. No storage battery locomotive possessing sufficient power capacity to meet the requirements of the switching service of Chicago has been built, and those interested in the manufacture of such equipment have not hesitated to say that a proposition to supply such a locomotive, while presenting no theoretical difficulties, involves details in design which have not as yet been perfected. An illustration of a storage battery mine locomotive built by the General Electric Company is presented as fig. 444.

Assuming that a storage battery locomotive of sufficient power may be produced, it will be of interest to consider briefly some effects which would be brought about by its introduction. The battery for such a locomotive would probably be most conveniently arranged in one or more battery tenders. Where the locomotive service is required to be continuous, duplicate sets of tenders should be available, in order that one set may be at its recharging station while the other is at work. These tenders would necessarily be both bulky and

FIG. 444. STORAGE BATTERY MINE LOCOMOTIVE, BUILT BY THE GENERAL ELECTRIC COMPANY

heavy, precise values depending upon the amount of work which they may be designed to perform between chargings. In ordinary yard service, their weight would add materially to, or might even equal, the weight of the average load now handled by steam locomotives in such service.

Incident to the use of the storage battery locomotive, there must be provided a power plant of substantially the same character and capacity as that which would be required if a normal electric locomotive were used. Although the storage battery locomotive possesses the advantage of being capable of operating over tracks not equipped with an electric contact system, transmission lines from the power plant to distributing points along the railroad must be provided, and there must be charging stations consisting of short sections of some form of contact which, in effect, would constitute a rudimentary contact system. Between the storage battery and the wheels must be electric motors and all the control apparatus which goes to make up the equipment of any electric locomotive. Substantially all details necessary to a complete electric contact installation are present except the contact system itself, and a portion of this must be included. Obviously, an electric locomotive operated from a contact system offers, in its command of power, in continuity of service and in celerity of movement made possible by low weight per unit power available, a more effective instrument for work than a locomotive which is propelled by power from a storage battery.

In estimating the relative cost of the storage battery locomotive and of the normal electric locomotive which receives its power by means of a contact system, consideration must be given to the various physical and operating conditions involved in the installation. As a basis for an analysis of the results to be expected in yard service, the Committee has considered the work involved in a freight yard aggregating 20 miles of track, and requiring constantly, both day and night, five switching locomotives of specific capacity. To meet such requirements, estimates have been made of the initial cost and of the operating results, assuming (1), the use of storage battery locomotives and (2), the use of electric locomotives receiving power from a continuous contact system. Without attempting to define the process completely, the results show that the initial cost of the storage battery locomotives will be several times as great as the initial cost of the contact system and electric locomotives. The cost of storage battery locomotives would, of course, diminish if the activities of the yard were reduced. The rate of depreciation of any form of storage battery now in service is much greater than that of any form of contact system.

The cost of operation will be greater for the storage battery locomotive than for the locomotive which is energized from a continuous contact system. The storage battery constitutes an additional element which is interposed between the power house and the wheels of the locomotive, and the efficiency with which the energy at the power house is transformed into energy at the locomotive draw-bar is thereby reduced.

From the foregoing brief discussion of the problem, it is apparent that the storage battery locomotive has not yet been developed to a point of commercial feasibility for heavy traction in connection with the operation of steam railroad terminals.

204.09 Conclusions Concerning the Feasibility of Eliminating the Steam Locomotive from the Railroad Terminals of Chicago and of Meeting all Operating Requirements without Resort to Complete Electrification: The preceding review is descriptive of a rapidly developing art. Great possibilities are presented for those who are interested in perfecting the various types of locomotives to which reference has been made. No one can foretell what the future may bring forth. Basing judgment upon the present-day achievement,* the following general conclusions seem to be justified:

1. There is available at this time no form of locomotive, carrying its own power and capable of handling the traffic of the Chicago railroad terminals, which could be substituted for the steam locomotive, and there is no prospect of the immediate development of any such locomotive.
2. The design of a gasoline internal combustion locomotive capable of handling the traffic of the Chicago terminals would involve such a multiplication of engine cylinders as to make its adoption almost, if not quite, prohibitive.

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* April, 1914.

3. The adoption of a gasoline internal combustion locomotive, should the design of such a machine become practicable, would not insure smokeless operation. As in the case of an automobile engine, such machines emit smoke when starting, and the amount of the smoke discharged is a function of the power developed.

4. The possibilities of an internal combustion locomotive, in which the source of power is an oil engine, constitute a promising field for work. No such locomotive, possessing the power of a modern steam locomotive, has thus far been developed. The elaborate experiments of Dr. Rudolph Diesel are significant, but the results derived from them do not indicate that the problem of design has been solved.

5. The adoption of an oil engine locomotive of the Diesel type, assuming the details of a satisfactory design to have been worked out, will not in itself suffice to secure smokeless operation. Oil engines are smokeless only when the fuel and air supply are adjusted to suit the load. Whether an oil engine will be more or less objectionable, because of its smoke, than the existing steam locomotive, can be determined only by tests under service conditions.

6. The compressed air storage locomotive, the hot water storage locomotive and the storage battery locomotive are all devices which, judged by the present state of the art, can be made serviceable only under special or peculiar conditions where more efficient devices cannot be used. It is not to be expected that such locomotives can be introduced for general work in the Chicago terminals.

7. There are certain short stretches of track in yards and industries to which it appears impracticable to apply any form of electric contact system; in the event of the complete elimination of the steam locomotive from the Chicago terminals, it would be practicable to work this trackage with some one of the specialized forms of locomotive described, notwithstanding the fact that no one of these locomotives is sufficient for the general work of the terminals.

8. The self-propelled motor cars of any of the various types described are most valuable for a light, diversified and not too frequent traffic. The field of usefulness for such cars within the limits of the Chicago terminals, where business is segregated and the passenger movement heavy, is not extensive.

9. The complete elimination of the steam locomotive from the railroad terminals of Chicago would, under present conditions, necessitate the abandonment of the service or the complete electrification of these terminals.

205. THE ELECTRIFICATION OF STEAM RAILROADS—A REVIEW*

SYNOPSIS: This chapter sets forth the more important details of the electrification of various steam railroads in America and in foreign countries, and presents for each electrification a statement of the mileage involved, the density of traffic, the character and amount of equipment used, the power requirements and other physical and technical characteristics.

205.01 General Considerations — American Electrifications: Before attempting a discussion of the conditions to be met in providing for the electrification of Chicago's railroad terminals, it will be of interest to review with some care the work accomplished in steam railroad electrification in America and in other countries.

No reference is made in this review to electric traction on the so-called American "interurban" railways, which differs in several important respects from electric traction under steam railroad conditions. The traffic of American steam roads embraces all classes of transportation, its movements involve heavy train units and it requires extensive terminal and freight handling facilities; that of the interurban lines involves passenger transportation by means of relatively light train or car units and a limited freight traffic which can be handled without the use of extensive terminal facilities. The operation of steam roads is usually conducted over privately owned rights-of-way while the interurban road frequently passes through the streets of towns or along highways between towns.

The sections which follow present brief descriptions, illustrated by maps, of electrically operated railroads in America and in foreign countries. Efforts have been made to insure the complete accuracy of the brief statistical record presented as a part of each description. The facts have in most cases been checked by an official of the road to which they refer, and acknowledgment is here made of the generous attention extended the Committee in this connection by busy men in many parts of the world.

In order that the purpose of each electrification may be set forth clearly, the descriptions are grouped according to the primary or guiding considerations which led to each undertaking. The classification of American electrifications is as follows:

Class I. Terminal Operation

This class embraces steam railroads which have electrified their terminals in large cities for one or both of the following reasons:

1. To accommodate the requirements of an underground station and approaches which, because of conditions of ventilation, necessitated the use of some motive power other than steam.
2. To provide for an increase in the capacity of city terminals in cases where physical enlargement under steam operation could have been made only at excessive cost or was considered impracticable for other reasons. In such cases the desired increase in capacity was accomplished by substituting motor car trains or electric locomotives for trains hauled by steam locomotives.

Class II. Main Line Operation

This class includes railroads which operate electrically a part or all of their lines for considerable distances across country and which handle full weight passenger or freight trains at speeds equivalent to those prevailing in ordinary steam operation. In some cases, the electrification has been due to the necessity of operating into an underground city terminal under conditions which required the electrification of a considerable extent of line beyond the terminal in order to make electric terminal operation practicable. In other cases, main line electrification has been undertaken to meet the competition of electric trolley lines, to increase the capacity of a line on heavy grades or to take advantage of power from hydraulic developments available at low cost in districts where coal is expensive.

Class III. Suburban Operation

In this class are included railroads which conduct suburban business by electric locomotives or motor car trains. Electrification of such railroads has been undertaken, in some cases, as an experiment for the purpose of determining the

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* The data and information upon which this review of electrification projects is based, are preserved in the Archives of the Committee, Vol. L 7.

effect upon traffic and upon operating costs; in other cases, to meet the competition of interurban lines in the same territory; and, in still other cases, suburban electrification has been incidental to terminal or main line electrification and has been undertaken as an operating necessity.

Class IV. Tunnel Operation

This class includes steam railroads which have electrified an important tunnel link in their main lines, without extending the electrification beyond the portals of the tunnel for a distance greater than necessary to conduct traffic through the tunnel by electric locomotives. Such electrifications have usually been made necessary or desirable because of the difficulties encountered in operating heavy traffic through long tunnels by steam locomotives.

205.02 General Considerations — Foreign Electrifications: The descriptions of foreign undertakings cannot be grouped according to the classification employed in presenting those of American roads. In foreign countries, physical conditions and methods of operation are often quite different from those in this country. While there are several examples of foreign trunk line railroad electrification, more attention has been given abroad to the electric operation of "secondary" lines, which possess some of the characteristics of the American interurban railway. Electric operation has also been applied in foreign countries to classes of roads having light service requirements, not directly comparable to any class of American railroads. Electrification of such roads is of interest as indicating the special adaptability of electric traction to peculiar conditions of operation.

The descriptions of electrifications on foreign roads are grouped by countries according to the following classification:

Class A. Trunk Line Railroads

This class includes steam trunk line railroads which have been electrified to meet the competition of electric trolley roads or tramways, to provide a more rapid and frequent passenger train service, to relieve congestion at terminals, to utilize available cheap power, or to overcome objectionable features of steam operation through tunnels or subways.

Class B. Secondary Railroads

This class includes secondary railroads which are not a part of trunk line systems and which, in general, correspond to American heavy suburban or interurban operation. They are included in order that there may be of record a definite statement concerning projects of which the American reader already has some understanding. The purposes of such electrifications have been to reduce operating costs under exceptional physical conditions, such as heavy grades, sharp curves, numerous or long tunnels; to utilize cheap power which could be easily obtained; to offer greater comfort to passengers for the purpose of attracting an increase in traffic; or to provide more frequent and more rapid service for the accommodation of growing traffic.

Class C. Light Service Railroads

Included in this class are a few examples of very light electrified train service conducted under difficult physical conditions. These electrifications illustrate tendencies regarding the character of electric systems most widely developed abroad.

AMERICAN RAILROAD ELECTRIFICATIONS

205.03 Class I — Terminal Operation — Long Island Railroad: The Long Island Railroad is essentially a passenger line serving suburbs of New York City and, at certain seasons, operating a heavy excursion business to the seashore of Long Island. A network of the lines of this road covers the western end of the island and delivers heavy commuter and excursion traffic to the Brooklyn and Manhattan terminals. Electrification of practically the entire network of lines on Long Island within a radius of 25 miles of New York City, comprising some 88 miles of route, has been completed; the lines are now in operation and furnish frequent and quick service, without transfer, from the heart of Manhattan and Brooklyn boroughs of New York to the terminus of the commuter zone. This represents the first complete electrification of a steam railroad on a large scale and is the most extensive example of multiple-unit passenger train service in operation.

The primary purpose of this electrification was to fulfil the requirements for smokeless operation through a new tunnel into a new underground passenger terminal located in the central part of the Borough of Brooklyn. The physical improvement of the terminal was undertaken as the result of the deliberations of a Commission formed in 1896 by the city of New York, for the purpose of recommending some practical plan for overcoming objectionable conditions in Atlantic Avenue, Brooklyn, due to the presence of railroad trains on the street surface. This Commission proposed a plan providing for a series of subways and elevated structures carrying the tracks under and over the undulating surface of the street for a distance of 5.25 miles. The report resulted in the adoption by the State Legislature, in May, 1897, of what is known as the Atlantic Avenue Improvement Act, approving the Commission's plan and requiring that some power other than steam be used for operating trains over this portion of the railroad. The adoption of this terminal plan, therefore, was predicated upon the use of electric motive power and had far-reaching consequences in compelling electric operation on an extensive railroad system. The decision of the railroad company, made at a later date, to operate trains into the new underground Pennsylvania Station in New York City, further emphasized the necessity for electrification, and finally electric traction was adopted upon the entire western division of the railroad.

The suburban and excursion business is operated by multiple-unit motor car trains, while a few express trains to the eastern end of the island are operated by electric locomotives from the Pennsylvania Station to the transfer yard at Long Island City, at which point steam locomotives are attached. Freight service is conducted by steam locomotives exclusively, and on some portions of the electrified system steam locomotives are also used to operate through passenger trains.

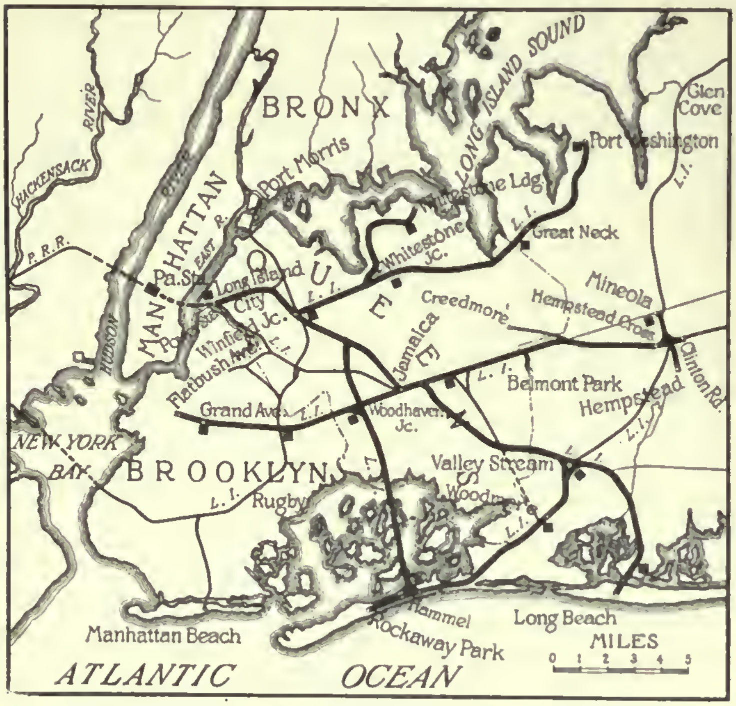

FIG. 445. ELECTRIFIED LINES OF THE LONG ISLAND RAILROAD

The system of traction employs direct current at 650 volts with third rail contact. Power is supplied by the generating station of the Pennsylvania Railroad Company at Long Island City and is transmitted as high tension alternating current to substations along the line, at which points it is reduced in potential and converted into direct current. Complete records of operating and maintenance costs extending over a period of eight years have been kept by the railroad company.

General statistics of the installation are as follows:

DATE OF INITIAL ELECTRIC OPERATION

Flatbush Avenue, Brooklyn, to Rockaway Park	June, 1905
Woodhaven Junction to Jamaica	Aug., 1905
Jamaica to Belmont Park	Oct., 1905
Jamaica to Springfield Junction	Oct., 1905
Springfield Junction to Valley Stream	Dec., 1905
Queens to Hempstead	May, 1908
Long Island City to Jamaica and Woodhaven Junction via Woodside and Hammel to Valley Stream	June, 1910
Pennsylvania Station, New York, to Woodside	Sept., 1910
Valley Stream to Long Beach	Sept., 1910
Winfield to Whitestone Landing	Oct., 1912
Whitestone Junction to Port Washington	Oct., 1913

MILEAGE

Total route miles, main line		88.63
Total track miles, main line	187.08	
Total miles, yard and siding	20.89	
Total miles of electrically equipped track		207.97

TRAIN SERVICE

Passenger, express	Multiple-unit trains
Passenger, local	Multiple-unit trains

AVERAGE NUMBER OF CARS PER TRAIN

Passenger	4.1

AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)

Passenger, express	95
Passenger, local	361

ELECTRIC TRAIN EQUIPMENT

Motor cars	414
Trailer cars	97

TRAIN-MILES PER ANNUM (1913)

Passenger, total	2,939,439

CAR-MILES PER ANNUM (1913)

Passenger, total	12,043,520

TRACTION POWER REQUIREMENTS (1913)

Maximum one-hour load, kw.	20,689
Total per annum, kw-hr.	54,590,951

The accompanying map, fig. 445, shows the location of the electrified lines of the Long Island Railroad and the location of substations.

205.04 Class I — Terminal Operation — New York Central & Hudson River Railroad: The electrification of this railroad embraces all the trackage of the remodeled Grand Central Station and yards, and that of about 30 miles of route serving a suburban territory along the main lines of the Hudson and the Harlem divisions.

The purpose of this electrification was to eliminate the smoke and objectionable gases arising from steam locomotives in the long tunnel entrance to the Grand Central Station in New York City. The presence of smoke and steam in this tunnel so obscured the signals that train speeds were necessarily restricted and the capacity of the line materially reduced. Accidents due to obscured signals occurred, and one of these with a large list of fatalities finally resulted in the enactment by the state, in 1903, of legislation which compelled the railroad to perfect plans for discontinuing the use of steam locomotives in the tunnel. The adoption of electric motive power for operation through the tunnel enabled the railroad to make plans providing for a large increase in the capacity of the terminal by utilizing the sub-surface areas for its yard and station tracks. As a result the entire terminal has been rebuilt. The electrification of the main line sections of the Hudson and Harlem divisions was necessary in order to secure continuous operation of the large number of local trains to the ends of runs within the suburban limits. With the main line sections electrified for suburban business, it became desirable to operate through business over these sections electrically. This has made it possible to remove the locomotive terminals from the congested area of the city.

The traffic consists of heavy main line express and suburban trains. The express trains are handled by electric locomotives and suburban service by multiple-unit motor cars. The schedule speed of the express trains has not been changed under electric operation, but, by reason of the great accelerating capacity of the motor cars in runs with frequent stops, it has been possible to increase the speed of the local or suburban trains.

The system of traction adopted employs direct current at 650 volts with third rail power conductor. Current is generated in two power stations, built and operated by the railroad, and is transmitted as high tension alternating current to substations located along the lines, at which it is reduced in potential and converted into direct current. The substations contain storage batteries which equalize the load and act as a reserve. Up to the present date the operation has been complicated by the reconstruction of the terminal so that operating costs are not considered representative.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION (MULTIPLE-UNIT)

Grand Central Station to High Bridge on the Hudson Division, and to Wakefield on the Harlem Division	Dec., 1906

DATE OF INITIAL ELECTRIC OPERATION (LOCOMOTIVE)

Grand Central Station to High Bridge on the Hudson Division, and to Wakefield on the Harlem Division	Jan., 1907

DATE OF COMPLETE CHANGE OF MOTIVE POWER

Date	Aug., 1907

DATE OF EXTENSIONS

High Bridge to Yonkers, Hudson Division	April, 1908
Wakefield to North White Plains, Harlem Division	Mch., 1910
Yonkers to Hastings, Hudson Division	April, 1911
Hastings to Tarrytown, Hudson Division	Nov., 1911
Tarrytown to Croton (Multiple-unit) Hudson Division	June, 1913
Tarrytown to Harmon (locomotive), Hudson Division	June, 1913

MILEAGE

Total route miles, main line		52.60
Total track miles, main line	177.00	
Total miles, yards and siding	67.60	
Total miles of electrically equipped track		244.60

TRAIN SERVICE

Passenger, through	Locomotives
Passenger, local	Multiple-unit trains and locomotives

AVERAGE NUMBER OF CARS PER TRAIN

Passenger, through	9
Passenger, local	6

AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)

Passenger, through	151
Passenger, local	126

ELECTRIC TRAIN EQUIPMENT

Locomotives, passenger	63
Motor cars	192
Trailer cars	19

TRAIN-MILES PER ANNUM (1912)

Passenger, through and local	1,880,014

CAR-MILES PER ANNUM (1912)

Passenger, local	4,974,487
Freight	140,000

TRACTION POWER REQUIREMENTS (1912)

Maximum one-hour load, kw. (approximate)	20,000
Total per annum, kw-hr.	54,402,837

The accompanying map, fig. 446, shows the location of the electrified lines of the New York Central & Hudson River Railroad.

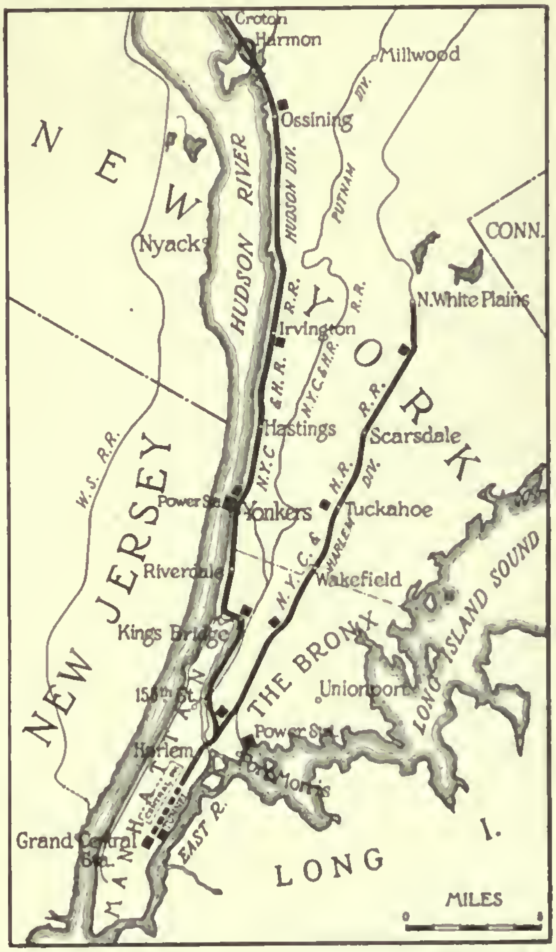

FIG. 446. ELECTRIFIED LINES OF THE NEW YORK CENTRAL & HUDSON RIVER RAILROAD

205.05 Class I—Terminal Operation—New York, New Haven & Hartford Railroad: The New York, New Haven & Hartford Railroad operates its passenger traffic into New York City, over tracks owned by the New York Central & Hudson River Railroad, from Wakefield on the Hudson Division to the Grand Central Station, a distance of 12.6 miles. Initially, the New Haven Railroad electrified its tracks from the junction with the New York Central tracks at Wakefield, N. Y., to Stamford, Conn., a distance of 20.9 miles. Later the Harlem River Branch, which extends south from New Rochelle on the main line to a point on the Harlem River opposite 129th Street, New York City, a distance of 11.5 miles, was electrified. This branch is a high-class freight and passenger line, of six and four tracks without grade crossings, and is located in a densely populated territory. It connects with the New York Connecting Railroad, which is under construction and will provide a through rail line to the western and southern states over a four-track bridge spanning the East River to Astoria, L. I., thence to a connection with the Pennsylvania Terminal Railroad in Long Island City. The Connecting Railroad line will be completed in the year 1916 and will be operated electrically. In 1913 the New Haven Railroad decided to extend its electrification to cover the entire main line to New Haven, Conn., a distance of about 40 miles from Stamford, thus providing a continuous run of 73.2 miles from Grand Central Station to New Haven over electrified tracks. Partial electric operation on this extension began in June, 1914, and thus all lines west of New Haven are now electrified for all classes of service. The total mileage of electrically equipped tracks embraces 76.57 route miles and 531.68 miles of single track. This electrification constitutes the most extensive electric operation, for heavy service on main lines, in existence on any steam railroad in the world.

The extensive electrification work of the New York, New Haven & Hartford Railroad was undertaken to conform with the plans of the New York Central Railroad for the electrification of its terminals. For this reason the electrification is included in the examples of terminal electrification, its great extension to main lines beyond the limits of the controlling section being due primarily to the operating necessity of conducting a continuous service to the limits of the local service zone.

Express passenger service is conducted between Grand Central Station and New Haven by electric locomotives; local passenger service is conducted partly by electric locomotive trains and partly by multiple-unit motor car trains. It is possible that in the near future all local service will be conducted by motor car trains. Freight trains are handled by electric locomotives from New Haven to the terminal freight yards located at four different points on the Harlem River Division.

The single-phase alternating current system of traction with overhead contact was chosen for the New Haven electrification because the plans of the company contemplated the eventual extension of electric traction over a long distance on the main line, for which purpose this system was considered more desirable than the direct current system with third rail which had been adopted by the New York Central Railroad. This decision, however, compelled the New Haven Company to arrange its electric equipment so that it could be operated within the direct current zone of the New York Central into the Grand Central Station as well as on the alternating current extension of the company's own lines. This decision introduced novel problems in electric traction, which were successfully solved by using a type of motor which may be operated on either system and by equipping the locomotives with two methods of current control and two methods of current collection adapted respectively to the third rail and the overhead working conductors along the lines. In the alternating current zone the tracks are equipped with an overhead catenary trolley wire system delivering single-phase alternating current at 11,000 volts. Current is generated in the company's power station at Cos Cob at 11,000 volts and fed into the trolley wires at suitable points at the same voltage. The first costs and operating expense of this installation could not be obtained.

General statistics of this electrification are:

DATE OF INITIAL ELECTRIC OPERATION		
Grand Central Station to New Rochelle (local trains)		July, 1907
New Rochelle to Portchester (local trains)		Aug., 1907
Portchester to Stamford (local trains)		Oct., 1907
DATE OF COMPLETE CHANGE OF MOTIVE POWER		
Locomotives		June, 1908
DATE OF INITIAL MULTIPLE-UNIT OPERATION		
Multiple-unit trains		Feb., 1910
DATE OF EXTENSIONS		
New Rochelle to Harlem River (also freight yards)		July, 1912
Stamford to New Haven		June, 1914
MILEAGE		
Total route miles, main line		76.57
Total track miles, main line	329.38	
Total miles, yard and siding	202.30	
Total miles of electrically equipped track		531.68
TRAIN SERVICE		
Passenger, through		Locomotives
Passenger, local		Locomotives and Multiple-unit trains
Freight		Locomotives
Switching		Locomotives

AVERAGE NUMBER OF CARS PER TRAIN*	
Passenger, through	5
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)*	
Passenger, through	64
Passenger, local	125
Freight	3
ELECTRIC TRAIN EQUIPMENT	
Passenger locomotives	41
Combined freight and passenger locomotives	7
Freight locomotives	36
Switching locomotives	16
Motor cars	27
Trailer cars	44
TRAIN-MILES PER ANNUM (FISCAL YEAR, 1912)*	
Passenger, total (per month)	96,046 to 124,151
CAR-MILES PER ANNUM (FISCAL YEAR, 1912)*	
Passenger, total (per month)	530,250 to 757,054
Freight, total (per month)	18,045 to 83,167
TRACTION POWER REQUIREMENTS (FISCAL YEAR, 1912)*	
Maximum one-hour load, kw.	15,400
Total per annum, kw-hr.	39,353,649

The accompanying map, fig. 447, shows the location of the electrified lines of the New York, New Haven & Hartford Railroad.

205.06 Class I—Terminal Operation—Pennsylvania Railroad, New York Tunnel Extension: The New York Tunnel Extension of the Pennsylvania Railroad embraces the following intimately related improvements:

FIG. 447. ELECTRIFIED LINES OF THE NEW YORK, NEW HAVEN & HARTFORD RAILROAD

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* Does not include the Stamford-New Haven extension.

1. An all-rail line to a centrally located station in New York City, replacing the existing terminal in Jersey City, which was formerly reached from New York by ferries only.
2. A downtown passenger terminal in New York City provided by the electrification of the present New York Division tracks from Newark to Jersey City, and the connection at the latter point with the line of the Hudson & Manhattan Railroad Company via tunnels under the North River to Church and Cortlandt streets, New York City.
3. Improvements on the Long Island Railroad, a controlled property, by which its main terminal is shifted from Long Island City to the New York Station.
4. An all-rail connection through New York City to the New England States for passenger traffic from the west and south. This will be accomplished by the New York Connecting Railroad from Sunnyside Yard, on the New York Terminal Railroad, to Port Morris, on the New York, New Haven & Hartford Railroad. The New York Connecting Railroad will bridge the East River at Hell Gate.

All these projects have been completed and are in operation, with the exception of the New York Connecting Railroad which is under construction. The Terminal Railroad is a new line connecting with the New York Division of the Pennsylvania Railroad at Manhattan Transfer, one mile east of Newark. It comprises a transfer yard at that point, a double track elevated line across the Hackensack Meadows and two tunnels under Bergen Hill and the North River to the Main Station at Seventh Avenue and 32d Street, New York City; thence it continues as a four-track railroad across the city and under the East River to a large make-up and storage yard in Long Island City, and connects with the Long Island Railroad.

This new line was electrified for the purpose of making practicable the operation of main line trains on heavy tunnel grades. Steam operation was not practicable because the station and yard of this great terminal were of necessity placed underground and were approached by long tunnels under the rivers bounding the city. The success of the whole terminal plan, therefore, was predicated upon the success of electric operation. This project has been classified as an example of "Terminal Operation" because the provision for a centrally located terminal station in New York City was the governing cause for the improvement plans undertaken by the railroad company. While the electrification includes about nine miles of main line, this portion is only incidental to the terminal electrification.

For all express trains over the Pennsylvania system, in both directions, interchange of motive power is made at Manhattan Transfer. Passengers for downtown New York change at Manhattan Transfer to motor car trains of the Newark Rapid Transit Line, which is jointly operated by the Pennsylvania Railroad Company and the Hudson & Manhattan Railway Company. This line delivers passengers at Exchange Place, Jersey City, and at the Hudson Terminal, Cortlandt and Church streets, New York. Local trains over the Pennsylvania Railroad, from points south of Newark on the main line and on the Long Branch Division, are still operated by steam locomotives into Jersey City, at which point passengers transfer either to ferries or to the Hudson Tunnel Line to New York. Freight traffic is not conducted over the Tunnel Line.

The direct current third rail system of electric traction was adopted. Current is supplied by the company's power station on the water front at Long Island City, where high tension alternating current is generated and transmitted to substations located along the line, at which points it is transformed to low tension, converted into direct current and fed into the conductor rails. No storage batteries are used in this installation. Detailed records of the operating costs of this traction system have been kept, but they furnish no direct comparison with steam operating costs as the service is an entirely new one. The unit costs of power and maintenance will, however, be useful in the consideration of the general case of heavy train operation by electric locomotives.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION

Manhattan Transfer, N. J., to Pennsylvania Station, New York City	Nov., 1910

DATE OF INITIAL MULTIPLE-UNIT OPERATION

Park Place and Manhattan Transfer, N. J., to Hudson Terminal, New York City (via Hudson & Manhattan Railway) . . .	Oct., 1911

MILEAGE

Total route miles, main line		18.73
Total track miles, main line	46.73	
Total miles, yard and siding	50.76	
Total miles of electrically equipped track . (New York & Manhattan Divisions, P. R. R.)		97.49

TRAIN SERVICE	
Passenger, through	Locomotives
AVERAGE NUMBER OF CARS PER TRAIN	
Passenger, through	6.4
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)	
Passenger, through	164
ELECTRIC TRAIN EQUIPMENT	
Passenger, locomotives	33
TRAIN-MILES PER ANNUM (1913)	
Passenger, through	492,547
CAR-MILES PER ANNUM (1913)	
Passenger, through	3,145,014
TRACTION POWER REQUIREMENTS (1913)	
Maximum one-hour load, kw.	12,180
Total per annum, kw-hr.	41,047,529

The accompanying map, fig. 448, shows the location of the electrified lines of the New York Tunnel Extension of the Pennsylvania Railroad.

FIG. 448. ELECTRIFIED LINES OF THE NEW YORK TUNNEL EXTENSION OF THE PENNSYLVANIA RAILROAD

205.07 Class I—Terminal Operation—Technical Characteristics: Table CCXXVI presents a summary of the general and technical characteristics of the electrifications of American steam roads included in Class 1—Terminal Operation.

205.08 Class II—Main Line Operation—West Jersey & Seashore Railroad: This railroad is one of the divisions of the Pennsylvania Railroad in southern New Jersey. The electrified portion comprises the longer of the two lines which this road operates from Camden to Atlantic City, the distance by this route being 64.6 miles. The electrification also includes 10 miles of the Cape May line from Newfield to Millville, N. J.

The conversion of this line from steam to electric operation was undertaken chiefly to ascertain the economic possibilities of main line electric traction and its effect on traffic. As the road traverses a populous suburban territory within 30 miles of Philadelphia and has its terminus at Atlantic City, its excursion and suburban business is large, thus affording unusual opportunity for the observation of this method of traction as applied to both long and short distance traffic.

Electric operation is conducted wholly by multiple-unit motor car trains, no electric locomotives being used. Rapid and frequent service is maintained for local traffic out of Camden, and through traffic is conducted by motor car express trains of from three to eight cars each. The coaches used are of standard steam railroad dimensions and weights. The maximum speed in express service is about 60 miles an hour and the average speed, with 22 miles between stops, is about 45 miles an hour. Freight trains and a number of passenger trains are operated over portions of the electrified system by steam locomotives.

Direct current at 650 volts with third rail working conductor is employed. Power is generated in a plant owned by the railroad and located near the Camden end of the line, and is transmitted as three-phase alternating current at 33,000 volts to substations located along the line at intervals of about eight miles, at which points it is converted to direct current and fed into the rails.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION		
Camden to Atlantic City and Newfield to Millville		Sept., 1906
MILEAGE		
Total route miles, main line		74.6
Total track miles, main line	147.8	
Total miles, yard and siding	2.46	
Total miles of electrically equipped track		150.26
TRAIN SERVICE		
Passenger, through		Multiple-unit trains
Passenger, local		Multiple-unit trains
AVERAGE NUMBER OF CARS PER TRAIN		
Passenger, total		3.7
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)		
Passengers, through		20
Passenger, local		60
ELECTRIC TRAIN EQUIPMENT		
Motor cars		109
TRAIN-MILES PER ANNUM (1913)		
Passenger, total		1,280,992

TABLE CCXXVI. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF AMERICAN STEAM ROAD ELECTRIFICATIONS
CLASS I—TERMINAL OPERATION

Details 1	Long Island Railroad 2	New York Central & Hudson River Railroad 3	New York, New Haven & Hartford Railroad 4	Pennsylvania R. R. New York Tunnel Extension 5
General:				
System of traction	Low tension direct current	Low tension direct current	Single-phase alternating current	Low tension direct current
Conductors:				
Type of working conductor	Third rail	Third rail	Overhead trolley	Third rail
Position	Over running	Under running	22 ft. above track	Over running
Size and material	Special steel 100 and 150 lb. per yd.	Special steel 70 lb. per yd.	Steel 0.46 in. equivalent diameter	Special steel 150 lb. per yd.
Type of collector	Cast iron slipper shoe	Cast iron under contact shoe	Pantograph sliding	Cast iron slipper shoe
Transmission voltage	11,000, 3-phase	11,000, 3-phase	22,000, single-phase	11,000, 3-phase
Contact voltage	650 direct	650 direct	11,000 single-phase	650 direct
Power Generation:				
Owner of plant	Purchased from Pennsylvania R. R.	Railroad Company	Railroad Company	Railroad Company
Number of plants and type	One steam-electric	Two steam-electric	One steam-electric	One steam-electric
Location	Long Island City	Yonkers and Port Morris	Cos Cob	Long Island City
Plant capacity (total, I-hr. rating)	20,689 kw. maximum load for electric traction	40,000 kv-a.	35,500 kv-a	38,500 kv-a.
Number of generators (total)	None	Eight	Eight	Seven
Rating and type	A.C. at 11,000 volts	5,000 kv-a. 11,000 v. 3-phase, 25-cycle	(Single-phase rating) 4-5,000 kv-a., 3-3,750 kv-a., I-4,250 kv-a., 11,000 v. 3-phase, 25-cycle	3-5,500 kw., 11,000 v. 3-phase, 25-cycle, 2-8,000 kw., 11,000 v. 3-phase, 25-cycle, 2-3,000 kw., 11,000 v. 3-phase, 60-cycle (for auxiliary power and lighting)
Type of prime mover	None	Steam turbine	Steam turbine	Steam turbine
Number of boilers (total)	None	32	28	36
Type	None	Water-tube	Water-tube	Water-tube
Rating	None	625 b. h. p.	14-625—14-525 b. h. p.	525 b. h. p.
High Tension Transmission:				
Feeders (circuit miles) —				
On poles (bare wire)	142.36	95	296 28	15
Underground (insulated cable)	33.23	58	None	30.1
Type	3-phase, 25-cycle	3-phase, 25-cycle	Single-phase, 25-cycle	3-phase, 25-cycle
Voltage	11,000 a. c.	11,000 a. c.	22,000 a. c. (stepped up by auto transformers with middle point grounded to track rails)	11,000 a. c.
Substations:				
Number and type	14 rotary, 2 portable rotary	9 rotary	None	4 rotary
Average distance apart (miles)	4 9	6.22	None	3.16
Capacity (total)	42,500 kw.	(Capacity each) 3,000 kw. 4,000 kw. 6,000 kw.	None	8,000 kw.
Size of rotary converter units	1,000 kw. 1,500 kw. 2,000 kw.	1,000 kw. 15,000 kw. 2,000 kw.	None	2,000 kw.
Size of transformer units	375 kv-a. 550 kv-a. 750 kv-a.	375 kv-a. 550 kv-a. 735 kv-a.	None	750 kv-a.
Rolling Stock:				
Locomotives or motor cars used	Motor cars	Locomotives and motor cars	Locomotives and motor cars	Locomotives and motor cars
Number in service	414 motor cars, 97 trailer cars	63 locomotives, passenger, 192 motor cars, 19 trailer cars	41 passenger, 7 passenger and freight, 36 freight, 16 switching locomotives, 27 motor cars, 44 trailer cars	33 locomotives, passenger, 66 motor cars
Train weight (average) excluding locomotive (tons, 2,000 lb.)	None	800	250—800 passenger, 1,500 freight	250—830
Locomotives:				
Class	None	4-8-4 0-4-4-4-4-0 0-4-4-4-4-0	(Most recent types) 2-4-4-2 * 2-4-4-2 † ¶ 0-4-4-0 ‡	4-4-4-4
Total weight (tons, 2,000 lb.)	None	121 118 132	110 * 120 † 80 ‡	156
Weight on drivers (lb.)	None	150,000 236,000 264,000	165,000 * 180,400 † 160,000 ‡	200,000
Number of motors	None	4 8 8	8 * 8 † 4 ‡	2
Type of motor	None	Direct mounted around axle	Geared to quill spring drive	Side rod drive
Capacity per motor (h.p., 1-hr. rating)	None	550 235 330	210 * 170 † 190 ‡	1,250 h. p.
Tractive effort of locomotive (lb., 1-hr. rating)	None	20,400 13,500 20,400	17,700 * 18,600 † 23,200 ‡	21,000
Normal speed of locomotive (rated load on level track) mi. per hr.	None	52 60 60	54 * 54 † 25 ‡	60
Motor Cars:				
Weight excluding passengers (tons)	41-60	53-57.5	87 ¶	36-55
Seating capacity	52-72	64	76	44-72
Number of motors	2	2	4	2
Capacity per motor (h.p., 1-hr. rating)	200-225	200	170	225-215
Trailer Cars:				
Weight excluding passengers (tons)	16-20	44	50	None
Seating capacity	24-56	64	76	None

* Freight locomotive. † Combined passenger and freight locomotives. ‡ Freight switching locomotive. ¶ Both a. c. and d. c. service.

CAR-MILES PER ANNUM (1913)	
Passenger, total	4,698,522
TRACTION POWER REQUIREMENTS (1913)	
Maximum one-hour load, kw.	10,500
Total per annum, kw-hr.	18,276,545

The accompanying map, fig. 449, shows the location of the electrified lines of the West Jersey & Seashore Railroad.

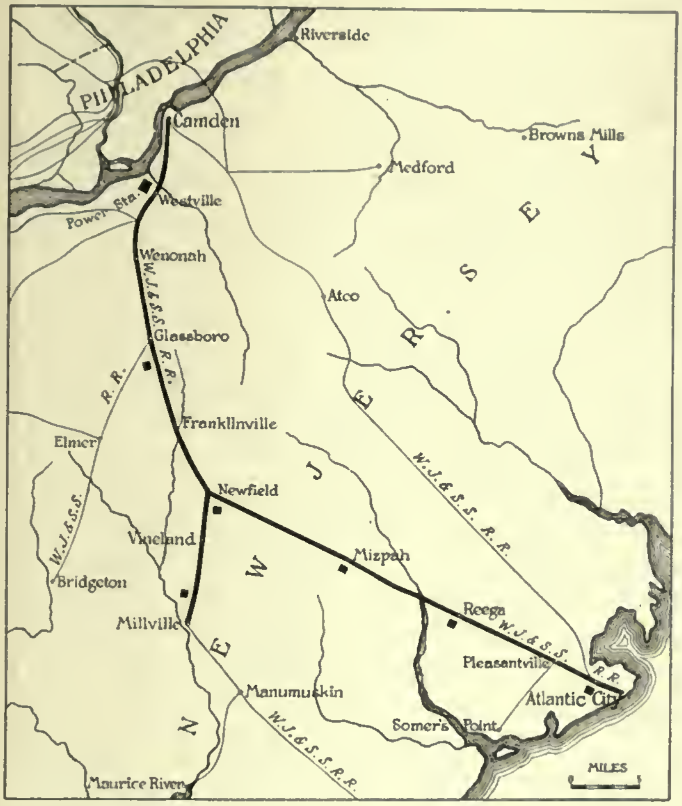

FIG. 449. ELECTRIFIED LINES OF THE WEST JERSEY & SEASHORE RAILROAD

205.09 Class II—Main Line Operation—Spokane & Inland Empire Railroad: This is a composite system operating interurban traffic, city traction and a freight and passenger business over a long single track railroad. The operation of the freight and passenger business alone is considered in this sketch as presenting an example of electric traction under steam railroad conditions. The terminus of the road is at Spokane, Wash.; the interurban division runs east as a 600-volt direct current line to Cœur d'Alene, and the freight and passenger division extends south as a single-phase alternating current line, to Colfax, Wash., and Moscow, Idaho. The road presents severe operating conditions for the electric equipment; there are several two per cent grades and twelve degree curves. The longest tangent is only about two miles in length.

This road was built for electric operation but its traffic and operating requirements are similar to those of steam trunk line railroads. It is an example of railroad construction undertaken for the purpose of stimulating the development of a new and rich farming country. Inasmuch as coal is expensive in this territory and water power for the generation of electricity is available on the line, it was thought that traffic could be handled at less cost and in a more satisfactory manner by employing electricity rather than steam as a motive power.

The freight business consists chiefly of grain and lumber which are handled in standard railroad freight cars hauled by electric locomotives, the average weight of the trains being 350 tons. The freight terminal in Spokane is advantageously located between the terminals of the Great Northern and the Northern Pacific railways, and is connected with these roads by transfer tracks for the interchange of freight. Two regular freight trains per day, one each way, are operated from both of the southern terminals, which gives a service of four freight trains per day on the main line. Passenger service on the main line, from Spring Valley Junction to Spokane, is conducted by motor and trailer cars in trains of from one to five cars. The schedule calls for twelve trains per day on the main line and for six trains on branch lines. Freight and express business is handled by motor cars and locomotives on the interurban division, which connects at Cœur d'Alene with the steamboat lines on the St. Joseph and the St. Marys rivers.

The freight divisions of the road are operated by the single-phase alternating current system, the installation being the first of its kind in this country for heavy long distance work. The interurban portion of the system, from Spokane to Cœur d'Alene, a distance of 32.5 miles, and the Spokane Traction Company's lines in the city, comprising about 52 miles, are operated with direct current at 600 volts with an overhead trolley wire. A hydro-electric station, located on the Spokane River about 9 miles from Spokane, develops power for the entire system. Power is generated as 2,200-volt, 60-cycle, alternating current, converted for the interurban and city lines to direct current, and is transmitted, through step-up transformers and frequency changers, as 45,000-volt, single-phase, 25-cycle, alternating current along the freight division to convenient points at which it is transformed to 6,600 volts and fed to the trolley wire. The contact system employed for the freight division is of the single overhead catenary wire construction.

General statistics of this system are as follows:

DATE OF INITIAL ELECTRIC OPERATION		
Spokane to Waverly		Sept., 1906
Waverly to Rosalia		April, 1907
Spring Valley Junction to Oakesdale		May, 1907
Oakesdale to Palouse		July, 1907
Rosalia to Colfax		July, 1907
Palouse to Moscow		Sept., 1908
MILEAGE		
Total route miles, main line		127.0
Total track miles, main line	129.5	
Total miles, yard and siding	1.5	
Total miles of electrically equipped track		131.0
TRAIN SERVICE		
Passenger		Multiple-unit trains
Freight		Locomotives
AVERAGE NUMBER OF CARS PER TRAIN		
Passenger		2.4
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)		
Passenger		12
Freight		4
ELECTRIC TRAIN EQUIPMENT		
Freight locomotives		11
Motor cars		15
Trailer cars		6
TRAIN-MILES PER ANNUM (1912)		
Passenger		395,598
CAR-MILES PER ANNUM (1912)		
Passenger		934,583
Freight		1,052,576
TRACTION POWER REQUIREMENTS (1913)		
Maximum one-hour load, kw.		2,450
Total per annum, kw-hr.		9,463,000

The accompanying map, fig. 450, shows the location of the electric lines operated by the Spokane & Inland Empire Railroad.

FIG. 450. ELECTRIFIED LINES OF THE SPOKANE & INLAND EMPIRE RAILROAD

205.10 Class II—Main Line Operation—Butte, Anaconda & Pacific Railway: This road is principally engaged in hauling copper ore from mines in the vicinity of Butte, Mont., to the smelters near Anaconda. It is an example of heavy freight electric operation under main line conditions. The electrified section of the road comprises about 30 route miles of single track, and, together with yards and sidings, embraces a total of 90.5 miles of track. The branch line from the Smelter Station to Washoe smelter, a distance of 6.8 miles, is not included in the route mileage given, as it serves only for shifting cars from the East Anaconda Yard to the smelter.

While it has not been possible to obtain exact information as to the object of this electrification, it is understood that, by means of electric traction, the company expected to increase the capacity of the line by hauling longer trains at higher speeds, and to effect operating savings by substituting cheap hydro-electric power for steam power developed by the burning of coal in steam locomotives.

The most important traffic consists of copper ore trains, the present movement amounting to about 5,000,000 tons per annum, or an average of 13,700 tons daily. Trains of 55 cars, weighing 3,740 tons, are handled against a ruling grade of 0.3 per cent on the main line, and trains of 1,400 tons, against a grade of 1.1 per cent on the Smelters Hill line. It is understood that traffic on the main line is conducted at considerably higher speed than was the case with the previous steam operation, and that on the Smelters Hill electric locomotives handle 25 per cent more tonnage than steam locomotives and make the run of 7.25 miles in about half the time previously required. Freight service is handled by electric locomotives exclusively, single or double electric units being used as required. The freight locomotives weigh about 80 tons, all on drivers, and are equipped with four 1,200-volt motors connected two in series to operate on the 2,400-volt line. The normal speed of the freight service is 21 miles per hour on level track. A certain amount of passenger service is also conducted by electric locomotives. At the present time this passenger traffic amounts to nine trains daily, averaging from three to four cars each. The passenger locomotives are of the same design as the freight locomotives, except that they are geared for a maximum speed of 45 miles per hour on level track.

This is the first example in this country of the use of 2,400-volt direct current for heavy electric traction. Current is generated in a hydro-electric plant of the Montana Power Company at Great Falls, Mont., and delivered as three-phase, 60-cycle current at 100,000 volts potential, to two substations on the line. In these substations the current is transformed to low potential and converted by motor-generator sets into direct current at 2,400 volts to be fed into overhead trolley wires. As full electric operation on this line was inaugurated very recently, statistics as to power requirements and operating results are not available.

The accompanying map, fig. 451, shows the location of the electrified lines of the Butte, Anaconda & Pacific Railway.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION		
East Anaconda to Washoe Smelter (freight)		June 3, 1913
Anaconda to Butte (passenger)		Oct. 1, 1913
East Anaconda to Rocker (freight)		Oct. 10, 1913
Rocker to Butte Hill (freight)		Oct. 20, 1913
MILEAGE		
Total route miles, main line		30.4
Total track miles, main line	30.4	
Total miles, yard and siding	60.1	
Total miles of electrically equipped track		90.5
TRAIN SERVICE		
Passenger		Locomotives
Freight		Locomotives
Switching		Locomotives
AVERAGE NUMBER OF CARS PER TRAIN		
Passenger		3.2
Freight		33.3
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)		
Passenger		9
Freight		73

* Freight train and car mileage are based on partial figures, as service was only begun during the month of October, 1913.

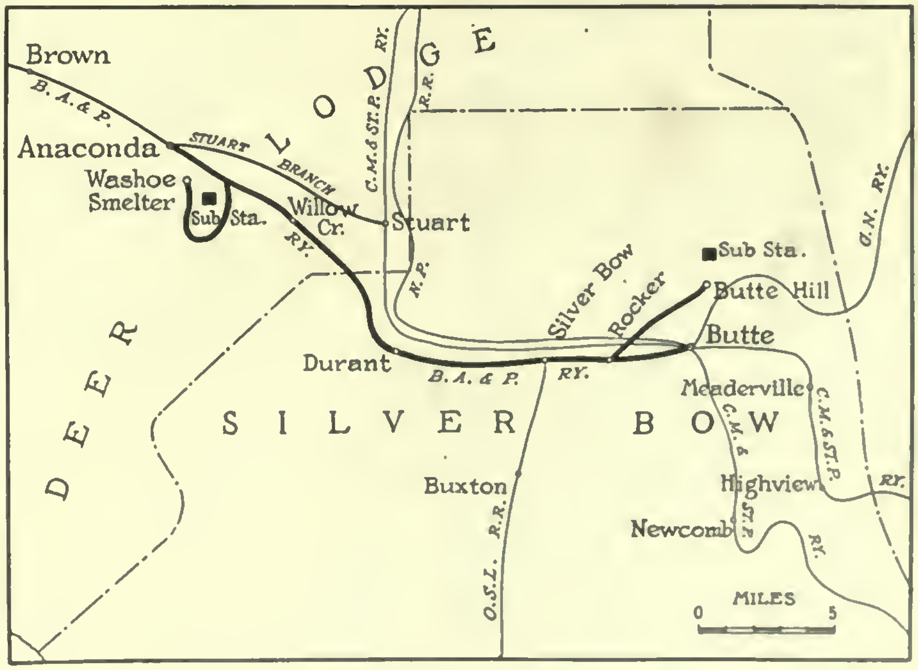

FIG. 451. ELECTRIFIED LINES OF THE BUTTE, ANACONDA & PACIFIC RAILWAY

ELECTRIC TRAIN EQUIPMENT

Passenger locomotives	2
Freight locomotives	15

TRAIN-MILES PER MONTH (OCTOBER, 1913)

Passenger	7,280
Freight	6,177

CAR-MILES PER MONTH (OCTOBER, 1913)

Passenger	23,408
Freight	205,850*

TRACTION POWER REQUIREMENTS (1913)

Maximum one-hour load, kw. (est.)	4,250
Total per annum kw-hr. (est.)	19,231,000

205.11 Class II—Main Line Operation—Technical Characteristics: Table CCXXVII presents a summary of the general and technical characteristics of the electrifications of American steam roads included in Class II—Main Line Operation.

TABLE CCXXVII. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF AMERICAN STEAM ROAD ELECTRIFICATIONS
CLASS II—MAIN LINE OPERATION

Details 1	West Jersey & Seashore Railroad 2	Spokane & Inland Empire Railroad 3	Butte, Anaconda & Pacific Railway 4
General:			
System of traction	Low tension direct current	Single-phase alternating current	High tension direct current
Conductors:			
Type of working conductor	Third rail	Overhead trolley	Overhead trolley
Position	Over running	22 feet above track	22 feet above track
Size and material	Steel 100 lb. per yd.	Copper 0.41 in. equiv. diam.	Copper 0.46 in. equiv. diam.
Type of collector	Cast iron slipper shoe	Pantograph sliding and pole trolley	Pantograph roller
Transmission voltage	33,000, 3-phase	45,000, single-phase	100,000, 3-phase
Contact voltage	650, direct	6,600, single-phase	2,400, direct
Power Generation:			
Owner of plant	Railroad Company	Railroad Company	Purchased from Montana Power Company
Number of plants and type	One steam-electric	One hydro-electric	Hydro-electric
Location	Westville	Near Spokane on the Spokane River	Great Falls, Mont.
Plant capacity (total, 1-hr. rating)	8,000 kv-a	12,000 kw.	4,250 kw.
Number of generators (total)	4	4	None
Rating and type	2,000 kv-a., 6,600 v., 3-phase, 25-cycle	3,000 kw., 2,200 v., 3-phase, 60-cycle	a.c. at 100,000 volts
Type of prime mover	Steam turbines	Hydraulic turbines	None
Number of boilers (total)	16	None	None
Type	Water-tube	None	None
Rating	358 b.h.p.	None	None
High Tension Transmission:			
Feeders (circuit miles)—			
On poles (bare wire)	138.6	110.4	None
Underground (insulated cable)	None	None	None
Type	3-phase, 25-cycle	Single-phase, 25-cycle	3-phase, 60-cycle
Voltage	33,000 a.c.	45,000 a.c.	100,000 a.c.
Substations:			
Number and type	8-rotary	10 static, 1 frequency changing station	3-motor generator
Average distance apart (miles)	9.9	12	26
Capacity (total)	17,000 kw.	15,250 kw.	6,000 kw.
Size of rotary converter units	500—1,000 kw.	None	None
Size of transformer units	185—370 kv-a	375 kv-a	
Rolling Stock:			
Locomotives or motor cars used	Motor cars	Locomotives and motor cars	Locomotives
Number and service	109 motor cars	11 freight locomotives, 15 motor cars, 6 trailer cars	15 freight locomotives, 2 passenger locomotives
Train weight (average) excluding locomotive (tons, 2,000 lb.)	None	350 freight	126 passenger; 600—3,740 freight (Depending on grade where operated)
Locomotives:			
Class	None	0-4-4-0 (Both a.c. and d.c. service)	0-4-4-0
Total weight (tons, 2,000 lb.)	None	52—72	80
Weight on drivers (lb.)	None	104,000—144,000	160,000
Number of motors	None	4	4
Type of motor	None	Geared to axle	Geared to axle
Capacity per motor (h.p., 1-hr. rating)	None	150—175	300
Tractive effort of locomotive (lb., 1 hr. rating)	None	10,500—22,000	30,000
Normal speed of locomotive (rated load on level track, mi. per hr.)	None	25—15	45 (passenger), 21 (freight)
Motor Cars:			
Weight excluding passengers (tons)	47—52	47	None
Seating capacity	36—72	38	None
Number of motors	2	4	None
Capacity per motor (h.p., 1-hr. rating)	200	125	None
Trailer Cars			
Weight excluding passengers (tons)	None	32	None
Seating capacity	None	62	None

205.12 Class III—Suburban Operation—Erie Railroad, Rochester Division: This electrification embraces a portion of the main line of the Erie Railroad extending from Rochester to Avon, N. Y., a distance of 19 miles, and a branch line to Mt. Morris, a distance of 15 miles, comprising a total route distance of 34 miles of electrically equipped track. The road is of single track construction with light grades. The territory traversed is a prosperous and well populated farming region. A local and interurban business of considerable density comprises the traffic.

This electrification was largely experimental, having been undertaken for the purpose of noting the effect of electric traction on traffic and on operating costs, especially in view of the cheap hydro-electric power available. The operation is said to have been successful.

Electric service is confined to passenger traffic. The trains are made up of multiple-unit motor cars, generally of two cars each, or of motor cars with steam coach trailers. Nineteen trains per day are operated, on the average, with a total equipment in service of eight motor cars and a few steam coach trailers. Through passenger trains to Rochester from eastern points, as well as freight trains over the electrified line, are handled by steam locomotives.

This is an early example of the use of single-phase alternating current traction on a steam railroad. Alternating current is supplied by the development of the Ontario Power Company at Niagara Falls, N. Y., and is transformed to the proper voltage and frequency for use in the overhead trolley construction of the railroad. The operation is not an extensive one and, therefore, the amount of power required is not large, the maximum being about 1,000 kilowatts.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION		
Rochester to Mt. Morris		June, 1907
MILEAGE		
Total route miles, main line		34
Total track miles, main line	34	
Total miles, yard and siding	4	
Total miles of electrically equipped track		38
TRAIN SERVICE		
Passenger		Multiple-unit trains
AVERAGE NUMBER OF CARS PER TRAIN		
Passenger		1.7
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)		
Passenger		19
ELECTRIC TRAIN EQUIPMENT		
Motor cars		8
TRAIN-MILES DAILY (1913)		
Passenger		517
CAR-MILES DAILY (1913)		
Passenger		900
TRACTION POWER REQUIREMENTS (1912)		
Maximum load, one-minute peak, kw.		955
Total per annum, kw-hr.		1,450,810

The accompanying map, fig. 452, shows the location of the electrified lines of the Erie Railroad near Rochester, N. Y.

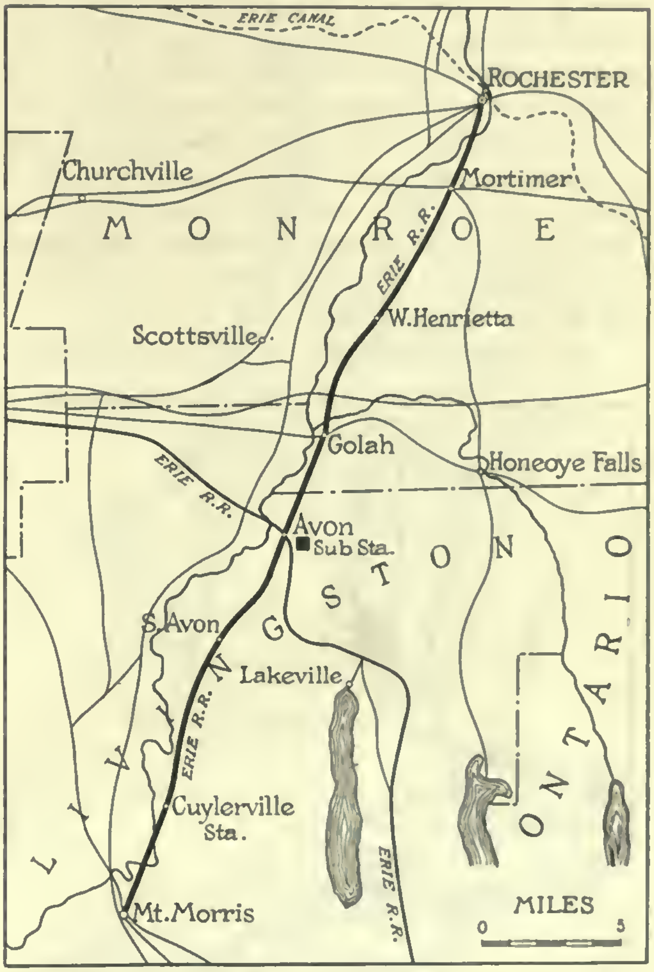

FIG. 452. ELECTRIFIED LINES OF THE ERIE RAILROAD NEAR ROCHESTER, N. Y.

205.13 Class III—Suburban Operation—Southern Pacific Railroad: This electrification embraces certain suburban lines of the Southern Pacific Railroad in and between the towns of Alameda, Oakland and Berkeley, Cal. While the electrification is quite extensive, comprising about

52 miles of route of which the greater part is a double track line, it includes a large extent of trackage in city streets. In some respects, therefore, it cannot be considered an electrification under steam railroad conditions. It is, however, an example in which heavy motor car trains take the place of trains previously hauled by steam locomotives, and is, therefore, given as an undertaking of an important steam railroad company to handle a large suburban traffic by electric traction.

A thickly settled community had grown up around the Southern Pacific terminal at Oakland during the 50 years of its operation, and steam service had been extended from time to time to serve the growing community, many of the extensions passing through the streets of towns. The operating disadvantages of these conditions, and the strong pressure of public opinion and of city authorities against the use of steam locomotives finally compelled a change in motive power. Moreover, it had become necessary to operate in competition with the fast electric service of a parallel suburban electric line.

The towns of Oakland, Alameda and Berkeley, Cal., comprise practically a continuous well populated district on the east side of San Francisco Bay, and include residential districts for large numbers of people engaged in business in San Francisco. This traffic is ferried across the bay and distributed by a network of lines to the towns and adjoining districts. Passenger traffic during the rush hours is heavy, requiring trains of six to eight cars at short intervals. Approximately 16,000,000 people are carried over the electric system of the Southern Pacific yearly. The trains are made up of steel motor cars and trailers of large capacity, of which 141 are in service. The road is operated by a multiple-unit system at a schedule speed of 22 miles an hour, with 0.68 mile average distance between stops. Certain trains run as express trains from the ferry mole for 2.5 miles without stop, and then make eight stops in the succeeding 5 miles. On the average, 783 trains are operated daily.

FIG. 453. ELECTRIFIED LINES OF THE SOUTHERN PACIFIC RAILROAD

Since portions of these lines are operated in city streets or highways, the overhead trolley system has been adopted. Direct current at 1,200 volts is employed. The railroad has erected a steam power station to furnish current for operation, and has also contracted with one of the hydro-electric power companies for an alternative source of power. No statistics of operating costs are available for this installation.

General statistics of this electrification follow:

DATE OF INITIAL ELECTRIC OPERATION JUNE, 1911		
MILEAGE		
Total route miles, main line		52.25
Total track miles, main line	100.81	
Total miles, yard and siding	14.00	
Total miles of electrically equipped track		114.81
TRAIN SERVICE		
Passenger, express		Multiple-unit trains
Passenger, local		Multiple-unit trains
AVERAGE NUMBER OF CARS PER TRAIN		
Passenger		2
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)		
Passenger, express		2
Passenger, local		783
ELECTRIC TRAIN EQUIPMENT		
Motor cars		81
Trailer cars		60
TRAIN-MILES PER ANNUM (FISCAL YEAR, 1912)		
Passenger		2,524,625

CAR-MILES PER ANNUM (FISCAL YEAR, 1912)	
Passenger	5,055,785
TRACTION POWER REQUIREMENTS (1912)	
Maximum one-hour load, kw.	6,900
Total per annum, kw-hr.	27,819,300

The accompanying map, fig. 453, shows the electrified lines of the Southern Pacific Railroad.

205.14 Class III—Suburban Operation—New York, Westchester & Boston Railway: This is an example of a high-class two and four track suburban railroad initially constructed for electric operation. It is owned by the New York, New Haven & Hartford Railroad, and operates from the latter's terminal station at 129th Street and Harlem River, New York City, over a portion of the Harlem River Division to a point near Westchester Avenue, a distance of 3.3 miles. Near Westchester Avenue the new line diverges from that of the New Haven Railroad and extends as a four-track line on private right-of-way for 6.8 miles to Mt. Vernon. At this point it divides, one line extending as a double track road for 9.4 miles to White Plains, and the other as a double track road for 2.1 miles to the main line of the New Haven Railroad at New Rochelle. The road is located in a country destined to be densely populated, which has not previously had rapid transit facilities. The road has no grade crossings on any of its lines, and is an excellent example of high-class railroad construction. It is equipped with a complete block signal system.

The franchise for this road had been in existence for a number of years, but construction was not undertaken until the property was acquired by the New Haven Railroad, which secured for the road a terminal in the city. The franchise is unusually restricted in that it specifies the minimum number of trains to be operated, the hours of service and the fare to be charged; it also specifies that the line must be operated by some motive power other than steam.

The traffic is almost entirely local passenger, although the road handles a small amount of freight. Multiple-unit trains of from one to three cars are run frequently, the schedule calling for about 93 express trains and 111 local trains daily. Based on present business,[*] the schedule is liberal. Local trains generally have one car only and express trains three cars. The cars are of steel and weigh 120,000 pounds completely equipped. They are 70 feet in length and have a seating capacity of 78 passengers.

The single-phase alternating current traction system is employed, making the equipment interchangeable with that of the New Haven Railroad. Power is taken from the Cos Cob plant of the latter road. No figures are obtainable in regard to operating costs.

The accompanying map, fig. 454, shows the location of the electrified lines of the New York, Westchester & Boston Railway.

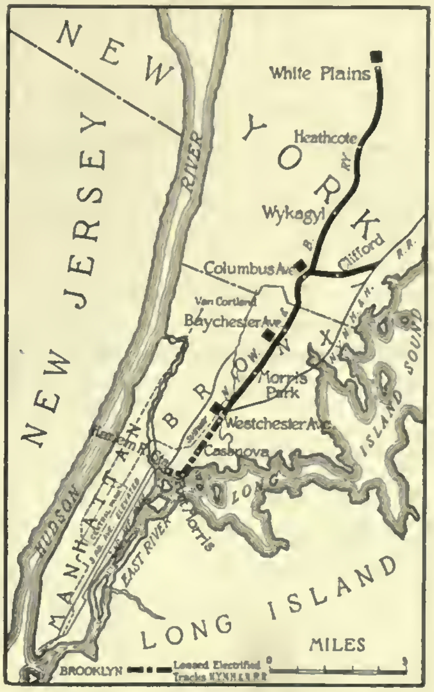

FIG. 454. ELECTRIFIED LINES OF THE NEW YORK, WESTCHESTER & BOSTON RAILWAY

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION		
180th Street to New Rochelle		May, 1912
Mt. Vernon to White Plains		July, 1912
180th Street to Harlem River Station		Aug., 1912
MILEAGE		
Total route miles, main line		18.23
Total track miles, main line	49.60	
Total miles, yard and siding	3.96	
Total miles of electrically equipped track		53.56
TRAIN SERVICE		
Passenger, express		Multiple-unit trains
Passenger, local		Single motor cars
Freight		Locomotives

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[*] In October, 1913, this amounted to 262,280 passengers.

AVERAGE NUMBER OF CARS PER TRAIN

Passenger, local	1
Passenger, express	3

AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)

Passenger, express	93
Passenger, local	111

ELECTRIC TRAIN EQUIPMENT

Motor cars	30
Freight locomotives	1

TRAIN-MILES PER MONTH (OCT., 1913)

Passenger	98,147

CAR-MILES PER MONTH (OCT., 1913)

Passenger	118,000
Freight	4,385

TRACTION POWER REQUIREMENTS (1913)

Maximum one-hour load, kw.	1,376
Total per annum, kw-hr.	7,200,000

205.15 Class III — Suburban Operation — Technical Characteristics: Table CCXXVIII presents a summary of general and technical characteristics of electrifications of American steam roads included in Class III — Suburban Operation.

TABLE CCXXVIII. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF AMERICAN STEAM ROAD ELECTRIFICATIONS, CLASS III—SUBURBAN OPERATION

Details 1	Erie Railroad 2	Southern Pacific Railroad 3	New York, Westchester & Boston Railway 4
General:			
System of traction	Single-phase alternating current	High tension direct current	Single-phase alternating current
Conductors:			
Type of working conductor	Overhead trolley	Overhead trolley	Overhead trolley
Position	21 ft. above track	22 ft. above track	22 ft. above track
Size and material	Steel 0.41 in. equivalent diameter	Copper 0.46 in. equivalent diameter	Steel 0.46 in. equivalent diameter
Type of collector	Pantograph sliding	Pantograph roller	Pantograph sliding
Transmission voltage	60,000, 3-phase	13,200, 3-phase	22,000, single-phase
Contact voltage	11,000, single-phase	1,200, direct	11,000, single phase
Power Generation:			
Owner of plant	Purchased from Ontario Power Company	Railroad Company	Purchased from N. Y., N. H. & H. R. R.
Number of plants and type	Hydro-electric	One steam-electric	One steam-electric
Location	Niagara Falls, Ontario, Canada	Fruitvale	Cos Cob
Plant capacity (total, 1 hr. rating)	955 kw. maximum load for electric traction	10,000 kw.	1376 kw. maximum load for electric traction
Number of generators (total)	None	2	None
Rating and type	A.C. at 60,000 volts	5,000 kw. 13,200 v. 3-phase 25-cycle	A. C. at 22,000 volts
Type of prime mover	None	Steam turbines	None
Number of boilers (total)	None	12	None
Type	None	Water-tube	None
Rating	None	645 b.h.p.	None
High Tension Transmission:			
Feeders (circuit miles)—			
On poles (bare wire)	14.0	27.0	46.26
Underground (insulated cables)	None	7.24	None
Type	3-phase, 25-cycle	3-phase, 25-cycle	Single-phase, 25-cycle
Voltage	60,000 a. c.	13,200 a. c.	22,000 a. c. (stepped up by auto transformer with middle point grounded to track rails)
Substations:			
Number and type	One static	4 rotary; one in power station	None
Average distance apart (miles)	None	6.27	None
Capacity (total)	2,250 kv-a.	15,000 kw.	None
Size of rotary converter units	None	Two 750 kw. in series	None
Size of transformer units	750 kv-a.	1,500 kv-a.	None
Rolling Stock:			
Locomotives or motor cars used	Motor cars	Motor cars	Motor cars
Number and service	8 motor cars	81 motor cars, 60 trailers cars	1 freight locomotive, 30 motor cars
Train weight (average) excluding locomotives (tons, 2,000 lb.)	None	None	
Locomotives:			
Class	None	None	0-4-4-0
Total weight (tons, 2,000 lb.)	None	None	79
Weight on drivers (lb.)	None	None	158,000
Number of motors	None	None	4
Type of motor	None	None	
Capacity per motor (h.p., 1-hr. rating)	None	None	192
Tractive effort of locomotive (lb., 1-hr. rating)	None	None	14,400
Normal speed of locomotive (rated load on level track, mi. per hr.)	None	None	25
Motor Cars:			
Weight excluding passengers (tons)	48—58	55	60
Seating capacity	34—70	88—116	78
Number of motors	4	4	2
Capacity per motor (h.p., 1-hr. rating)	100	125	170
Trailer Cars:			
Weight excluding passengers (tons)	None	33.5	None
Seating capacity	None	116	None

205.16 Class IV — Tunnel Operation — Baltimore & Ohio Railroad: The Baltimore & Ohio Railroad was the first road in America to employ electric power for hauling heavy passenger and freight trains. It was a bold experiment at the time (1895), involving as it did the building of traction motors of unprecedented power and the handling of heavy electric currents on the contact line. The electrified section, 3.7 miles in length, passes through the city of Baltimore, Md., and forms the link between the old terminus of the Washington-Baltimore line of the Baltimore & Ohio Railroad at Camden Station and the Mt. Royal Station of its new line from Philadelphia. A portion of the line, about 1.5 miles in length, is located in a tunnel and a long grade of 1.5 per cent is encountered northbound from Mt. Royal Station. Electrification has not been extended beyond the limits required to handle traffic through the tunnel and to provide a convenient point at which interchange of motive power can be made. The object of the installation was the elimination of the smoke and gases emitted by steam locomotives in a long tunnel.

Electric locomotives handle complete trains, including steam locomotives, from Camden Station, in the southern part of the city, through the tunnel to Mt. Royal Station and thence to the northern section of the city. As the ruling grade through the tunnel is in but one direction the trains are assisted only on the up-grade, the electric locomotives returning light. Trains running in the opposite direction are allowed to coast through the tunnel. All trains, both passenger and freight, are handled in this manner.

Direct current at 625 volts was originally supplied to the electric locomotives from a power station built and operated by the railroad, storage batteries being employed to provide a reserve. The power supply is now supplemented by current furnished under contract by a power company. The working conductor was originally an overhead steel "Z" bar. This was found to corrode rapidly through the action of discharges from steam locomotives and was also found to be too rigid for the successful collection of the current. This form of conductor was therefore abandoned and replaced by a third rail installed near the track. The construction and operating costs are regarded as being high.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION, 1895		
MILEAGE		
Total route miles, main line		3.7
Total track miles, main line	7.4	
Total miles, yard and siding	1.0	
Total miles of electrically equipped track		8.4
TRAIN SERVICE		
Passenger, through		Locomotives
Passenger, local		Locomotives
Freight		Locomotives
AVERAGE NUMBER OF CARS PER TRAIN		
Passenger, total		6
AVERAGE NUMBER OF TRAINS DAILY (EASTBOUND ONLY)		
Passenger, through		12
Passenger, local		6
Freight		12
ELECTRIC TRAIN EQUIPMENT		
Passenger and freight locomotives		4
Freight locomotives		5
TRAIN-MILES PER ANNUM (FISCAL YEAR, 1912)		
Passenger		19,302
Freight		45,166
CAR-MILES PER ANNUM (FISCAL YEAR, 1912)		
Passenger		115,812
TRACTION POWER REQUIREMENTS (1913)		
Maximum one-hour load, kw.		1,043
Total power per annum, kw-hr.		6,177,915

The accompanying map, fig. 455, shows the location of the electrified line of the Baltimore & Ohio Railroad running under the city of Baltimore.

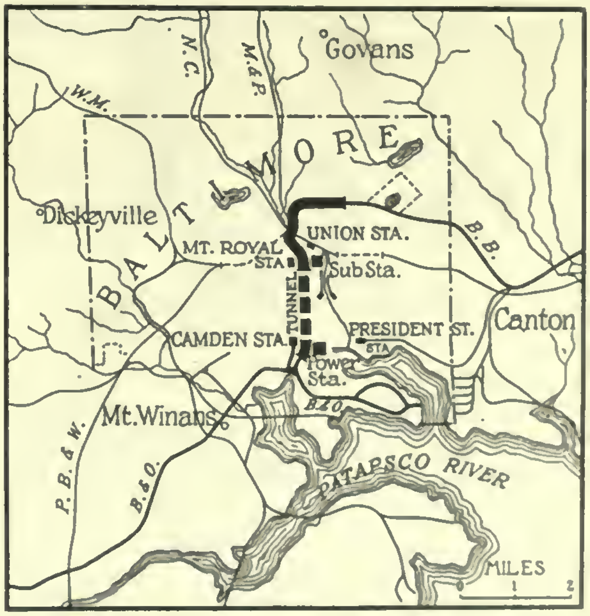

FIG. 455. ELECTRIFIED LINE OF THE BALTIMORE & OHIO RAILROAD—BALTIMORE TUNNEL

205.17 Class IV — Tunnel Operation — Grand Trunk Railway: The Detroit and Chicago extension of the Grand Trunk Railway passes under the St. Clair River through a tunnel from Sarnia, Ont., to Port Huron, Mich. The length of this tunnel from portal to portal is about 1.25 miles, and the total length of the tunnel and open cut approaches is 2.25 miles, all on 2.0 per cent grades descending toward the center of the tunnel. The tunnel is a tube containing a single track, with single track approaches. The electrification includes the tunnel and the approaches and yards at both ends, making a total of 3.8 route miles or 12 miles of single track.

FIG. 456. ELECTRIFIED LINE OF THE GRAND TRUNK RAILWAY—ST. CLAIR TUNNEL

From the date of the completion of the tunnel in 1890 until the date of its electrification in 1908, all traffic was handled by specially designed steam locomotives operating in the tunnel section as an independent division of the road. The locomotives hauled a maximum weight of 760 tons and were designed for high tractive effort at slow speeds on the grades. Under the limited train weight and speed, the constantly increasing traffic necessitated an increase in the capacity of the tunnel. The gases in the tunnel also proved not only objectionable, but dangerous in cases of trains breaking in two or stalling. Electrification was therefore decided upon as a means of eliminating dangerous atmospheric conditions and of increasing the capacity of the tunnel.

The tunnel section is operated by the St. Clair Tunnel Company as an independent division of the railroad. The steam road locomotive is cut off at the approach yard located at either end of the tunnel and an electric locomotive, either single or double unit as the case requires, is used for hauling the train over the electrified division. Both passenger and freight trains are operated in this manner. The electric locomotives are capable of hauling a 1,000-ton train from terminal to terminal in 15 minutes, with a maximum speed not exceeding 25 miles an hour and a minimum speed, when ascending the 2.0 per cent grades, of not less than 10 miles an hour. In this way three freight trains an hour may be hauled over the division and in emergencies four trains may be so handled.

The single-phase alternating current system, with overhead catenary trolley, is employed. As the clearances are very limited in the tunnel, it was considered advisable to limit the trolley voltage to 3,300 volts. Power is generated in a steam plant erected by the railroad near the portal of the tunnel on the Port Huron side of the river. No figures covering operating costs are accessible.

General statistics of this electrification follow:

DATE OF INITIAL ELECTRIC OPERATION, APRIL, 1908

MILEAGE		
Total route miles, main line		3.8
Total track miles, main line	6.5	
Total miles, yard and siding	5.5	
Total miles of electrically equipped track		12.0
TRAIN SERVICE		
Passenger		Locomotives
Freight		Locomotives
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)		
Passenger		18
Freight		33
AVERAGE NUMBER OF CARS PER TRAIN		
Passenger		6
Freight		26
ELECTRIC TRAIN EQUIPMENT		
Passenger and freight locomotives		3 (6 units)
TRAIN-MILES PER ANNUM (1913)		
Passenger		24,968
Freight		45,837
CAR-MILES PER ANNUM (1913)		
Passenger		149,811
Freight		1,191,769
TRACTION POWER REQUIREMENTS (1912)		
Maximum one-hour load, kw.		830
Total per annum, kw-hr.		3,396,453

The accompanying map, fig. 456, shows the location of the electrified line of the Grand Trunk Railway through the St. Clair Tunnel.

205.18 Class IV—Tunnel Operation—Great Northern Railway: This railroad crosses the summit of the Cascade Range of mountains in the state of Washington, through a single track tunnel about 2.6 miles long. The tunnel has a continuous grade of 1.7 per cent rising to the east, with long approach grade of 2.0 per cent or more for about 30 miles on either side of the summit. The road is operated electrically for a distance of 4 route miles or 7 track miles, including the tunnel and the yards at the approaches.

The main object sought by this electrification was the elimination of the smoke and gases emitted in the tunnel by steam locomotives, which made operation difficult and at times dangerous. These conditions made operation through the tunnel the limiting factor in the capacity of the line for hauling freight across the mountains.

Traffic consists of heavy main line freight and passenger trains. When approaching the tunnel from the west the freight trains are split into units of a maximum weight of about 1,500 tons, including the weight of one steam locomotive, and the train and steam locomotive are hauled through the tunnel by electric locomotives. Three electric locomotives are required for each freight train, a double unit at the head and a single unit at the rear. Passenger trains, including the steam locomotive, are hauled by a double electric unit at the head. As the summit of the tunnel is practically at the eastern portal, electric locomotives are not used for westbound traffic.

While the electrified section now includes only the tunnel and its approaches, it was anticipated that eventually the entire heavy grade division on both sides would be operated electrically. An electric plant was therefore designed with this end in view. The three-phase alternating current system with track rail return was adopted, and its use on this road is the first and only example of the application of the system in America. Power is supplied from a hydro-electric plant owned by the railroad, located near Leavenworth, about 30 miles east of the tunnel. Power is generated as three-phase, 25-cycle, 6,600-volt alternating current, and is stepped up to 33,000 volts for transmission to the tunnel, where it is lowered in pressure to 6,600 volts and fed into double overhead trolley wires. In the locomotives the current is reduced in potential to 500 volts and utilized in four three-phase induction motors designed to give a normal and constant locomotive running speed of 15 miles per hour. No figures are obtainable as to operating costs.

General statistics of this electrification follow:

DATE OF INITIAL ELECTRIC OPERATION, JULY, 1909		
MILEAGE		
Total route miles, main line		4.0
Total track miles, main line	4.0	
Total miles, yard and siding	3.0	
Total miles of electrically equipped track		7.0
TRAIN SERVICE		
Passenger		Locomotives
Freight		Locomotives
AVERAGE NUMBER OF CARS PER TRAIN		
Not available		
AVERAGE NUMBER OF TRAINS DAILY (EASTBOUND ONLY)		
Passenger		4
Freight		4
ELECTRIC TRAIN EQUIPMENT		
Passenger and freight locomotives		4
TRAIN-MILES PER ANNUM		
Not available, no record kept		
CAR-MILES PER ANNUM		
Not available, no record kept		
TRACTION POWER REQUIREMENTS (1912)		
Maximum half-hour load, kw.		4,000
Total per annum, kw-hr.		4,080,000

The accompanying map, fig. 457, shows the location of the electrified line of the Great Northern Railway through the Cascade Tunnel.

205.19 Class IV—Tunnel Operation—Michigan Central Railroad: The Detroit River acts as a natural barrier between two main divisions of the Michigan Central Railroad. The double track tunnel under this river, connecting Windsor, Ont., and Detroit, Mich., therefore forms a most important link in the system. The twin tunnels are each about 1.5 miles long from portal to portal, with a maximum grade of 2.0 per cent against westbound traffic and 1.5 per cent against eastbound traffic. Open cut approaches extend for some distance beyond the portals of the tunnel, giving a total length of 2.43 miles between summits. The entire electric zone, including yard tracks, comprises about 20 miles of single track.

It had long been recognized that the Detroit River, with the slow crossing of train ferries, especially in winter, was a serious detriment to the proper development of traffic in the territory served. Many plans had been made to solve the problem either by some type of bridge or by a tunnel. The depth of the stream, the swift current and the heavy boat traffic presented serious difficulties of an engineering and operating nature. After a demonstration of the physical possibilities of electric traction on other roads, it was decided that a tunnel offered a better solution of the problem than a bridge, which would require long and expensive approaches and heavy grades. Therefore, twin tunnels were built and equipped for electric operation.

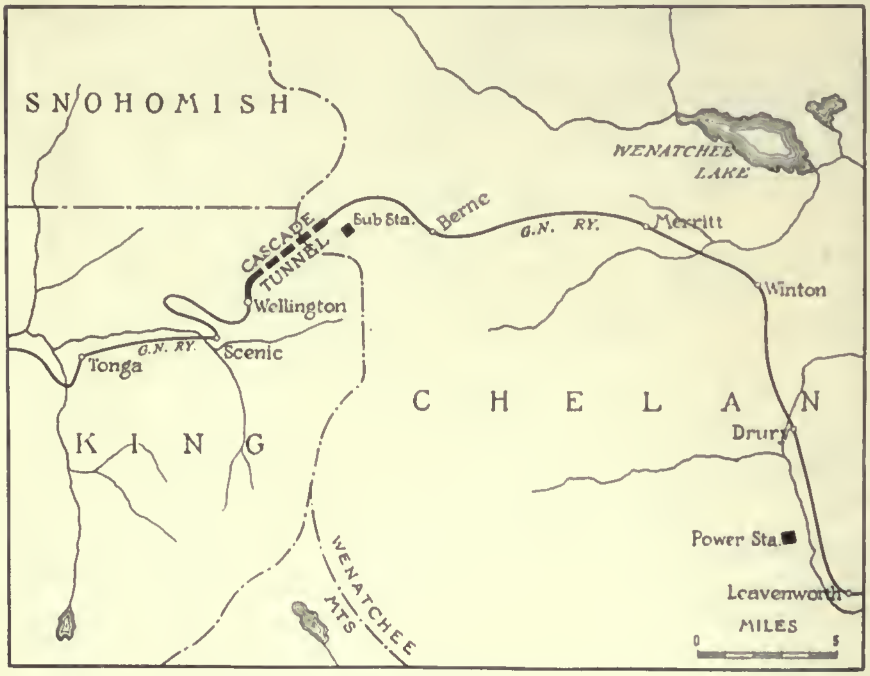

FIG. 457. ELECTRIFIED LINE OF THE GREAT NORTHERN RAILWAY CASCADE TUNNEL

As locomotive divisions terminate on either side of the tunnel, the method of operation employed for both freight and passenger trains is that of dropping the steam locomotives and attaching electric locomotives which haul the trains through the tunnel. Freight and passenger trains, averaging 800 tons and 310 tons respectively, are handled in this manner. The time saved, as compared with the old ferry method, amounts to 15 or 20 minutes in the case of passenger trains and three or four hours in the case of freight trains.

The system of traction involves the use of direct current with third rail, and is similar to the system in use on the New York Central & Hudson River Railroad.

Power is purchased from the Detroit Edison Company at 4,400 volts, three-phase, 60 cycles, and is delivered over two special cables to the tunnel company's substation on the Detroit side of the river near the tunnel shaft. Here it is transformed and converted, and fed to the third rail working conductor as direct current at 650 volts. The substation also contains a storage battery which serves to provide against periodic fluctuations on the Edison Company's plant, thus insuring greater reliability of service.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION, JULY, 1910

MILEAGE

Total route miles, main line		4.5
Total track miles, main line	9.0	
Total miles, yard and siding	11.0	
Total miles of electrically equipped track		20.0

TRAIN SERVICE

Passenger	Locomotives
Freight	Locomotives

AVERAGE NUMBER OF CARS PER TRAIN

Passenger	8.3
Freight	39.6

AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)

Passenger	20
Freight	30

ELECTRIC TRAIN EQUIPMENT

Passenger and freight locomotives	6

TRAIN-MILES PER ANNUM (1912)

Passenger	21,735
Freight	40,336

CAR-MILES PER ANNUM (1912)

Passenger	180,417
Freight	1,598,036

TRACTION POWER REQUIREMENTS (1912)

Maximum one-hour load, kw.	840
Total per annum, kw-hr.	3,355,000

The accompanying map, fig. 458, shows the location of the electrified line of the Michigan Central Railroad through the Detroit Tunnel.

205.20 Class IV — Tunnel Operation — Boston & Maine Railroad: The Hoosac Tunnel, which pierces the Berkshire Hills in western Massachusetts, is situated on the main line of the Boston & Maine Railroad, which connects Boston with Albany and the west. This tunnel is nearly five miles in length from portal to portal, and is the longest in America. Its construction covered a period of 24 years and represented an outlay of approximately $12,000,000. It was placed in operation in February, 1875. The tunnel itself has two tracks, and was built on a 0.5 per cent grade from each end toward the central shaft in order to provide drainage for the large amount of seepage water. The electric zone extends from North Adams Station to a point about one-quarter mile east of Hoosac Tunnel Station, a distance of approximately eight miles. The length of electrified single track, including the yards at North Adams, is 21.5 miles.

This is an example of tunnel electrification undertaken for the purpose of avoiding the smoke and gases incident to steam operation. The traffic is exceedingly heavy and congestion often resulted under steam operation. The adoption of electric operation, which has cleared the tunnel of smoke, permits a clear view of block signals in the tunnel and this allows two or more trains to operate on each track in the tunnel at the same time, thus greatly increasing the capacity of this portion of the line.

Both passenger and freight trains are operated by coupling the electric locomotive in front of the steam locomotive and hauling train and locomotive through the tunnel, the steam locomotive running light with fires undisturbed. An average of 16 passenger and 45 freight trains daily are handled in this manner. The freight trains average 29 cars and the passenger trains 6 cars.

The system of traction employs single-phase alternating current. This is supplied to the locomotive from an overhead trolley supported by a single catenary. Power is generated at 11,000 volts, three-phase, 25 cycles, in a steam plant located at Zylonite, about 2.5 miles south of the west portal of the tunnel near the Hoosac River. It is transmitted as single-phase current to the switch house located at the west portal.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION, MAY, 1911

MILEAGE

Total route miles, main line		7.97
Total track miles, main line	15.94	
Total miles, yard and siding	5.56	
Total miles of electrically equipped track		21.50

TRAIN SERVICE

Passenger	Locomotives
Freight	Locomotives

AVERAGE NUMBER OF CARS PER TRAIN

Passenger	5.8
Freight	29.2

AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)	
Passenger	16
Freight	45

ELECTRIC TRAIN EQUIPMENT	
Passenger and freight locomotives	5

TRAIN-MILES PER MONTH (JANUARY, 1913)	
Passenger	13,799
Freight	11,200

FIG. 458. ELECTRIFIED LINE OF THE MICHIGAN CENTRAL RAILROAD — DETROIT TUNNEL

CAR-MILES PER MONTH (JANUARY, 1913)	
Passenger	21,889
Freight	327,062

TRACTION POWER REQUIREMENTS PER ANNUM (1913)	
Maximum one-hour load, kw.	1,600
Total per annum, kw-hr.	6,642,160

The accompanying map, fig. 459, shows location of the electrified line of the Boston & Maine Railroad through the Hoosac Tunnel.

205.21 Class IV — Tunnel Operation — Technical Characteristics: Table CCXXIX presents a summary of the general and technical characteristics of the electrifications of American steam roads included in Class IV — Tunnel Operation.

205.22 American Electrification Projects under Construction or in Contemplation:* In addition to the electric traction installations described, there are at present five other important projects on American steam railroads either under construction or in contemplation. A brief description of each of these, based upon such information as is obtainable, is presented in the paragraphs which follow.

The Norfolk & Western Railway now has under construction a project for the electrification of a portion of its main line extending from Eckman, W. Va., on the west slope of the Alleghany Mountains, over the Elkhorn Summit to Bluefield, W. Va., a distance of 26 miles of route and about 90 miles of track. The grades are heavy, some stretches running as high as 1.5 and 2.0 per cent. One single track tunnel 0.6 mile long on a 1.5 per cent grade is located on this division. The traffic consists largely of heavy coal trains weighing as much as 3,250 tons, which are

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* 1914.

at present hauled at slow speed by Mallet locomotives, three locomotives being required to a train. Difficulties in ventilation have been the result of operating these trains through the tunnel with steam locomotives, and consequently the present capacity of the line is not adequate for the traffic. It is contemplated that electrification will insure a sufficiently large saving in operating expense to pay interest and depreciation on the electric equipment and leave a surplus in addition; also, that the electric facilities will be adequate for relieving the congestion of traffic. It will be possible under electric operation to increase the speed on heaviest grades from 7.5 to 14 miles an hour and to handle the heaviest trains with two instead of with three locomotives. Passenger trains and fast freight trains will continue to operate with steam locomotives over the electrified section. Power is to be supplied by a plant built by the railroad, and will be fed to the overhead trolley conductors as alternating current at 11,000 volts. Twelve electric locomotives, or 24 semi-units, have been purchased for this installation; these semi-units are of the double-truck articulated type, each truck having two driving axles and one radial axle. The physical conditions, the density of traffic and the unusual train make-up on the line will produce on this road the heaviest electric traction operation yet attempted.

The Pennsylvania Railroad is at present equipping for electric operation the portion of its main line extending from Broad Street Station, Philadelphia, to Paoli, on the line to Harrisburg, a distance of about 20 miles. This line consists of four main tracks, all of which are to be electrically equipped. The purpose of this electrification is to relieve the present congestion in the Broad Street Station which for several reasons cannot readily and quickly be enlarged. This relief, it is contemplated, will result from the operation of local electric multiple-unit trains which will not require as large a number of shifting movements as does the operation of steam trains. Through trains will continue to operate over this electrically equipped section with steam locomotives. The system to be used will employ single-phase alternating current at 11,000 volts with overhead trolley and single-phase motors on cars. Power is to be purchased from the Philadelphia Electric Company.

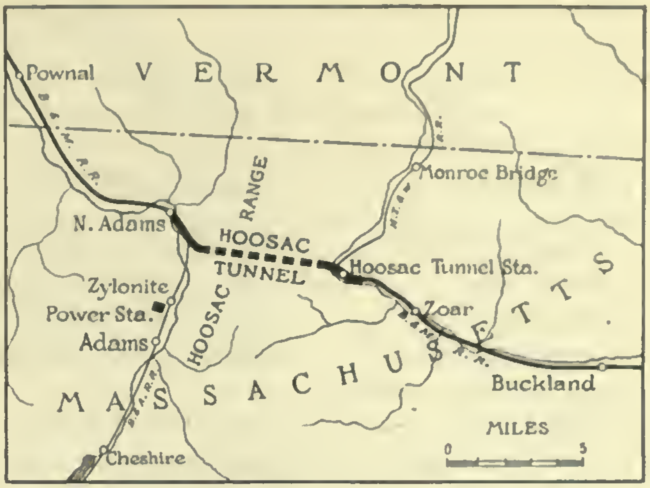

FIG. 459. ELECTRIFIED LINE OF THE BOSTON & MAINE RAILROAD—HOOSAC TUNNEL

The Canadian Northern Railway now has under construction in the city of Montreal, Que., a new terminal which is entered by means of a long tunnel. In order to facilitate the operation of trains in and out of this terminal, it has been decided to equip for electric operation about ten miles of double track running from the terminal to the Cartierville freight yards located beyond the town of Mt. Royal. Interchange of motive power is to be made at the Cartierville yards. It is understood that the power for this operation will be purchased and that the system of traction is to be direct current at 2,400 volts with overhead trolley wire. Electric locomotives will be employed for the operation of through trains, and multiple-unit motor car trains will be used for suburban service. The locomotives will weigh 80 tons and will be equipped with two 4-wheel articulated trucks with four motors geared to the drivers through twin gears.

The Chicago, Milwaukee & St. Paul Railway proposes to electrify a portion of the main line of its Pacific coast extension, embracing a stretch of about 440 miles across three mountain ranges from Harlowton, Mont., to Avery, Idaho. It is understood that the initial work will include only one division, that over the Rocky Mountains from Three Forks to Deer Lodge, Mont., on which the grades are heavy. Power for electric operation is to be purchased from the Montana Power Company, which controls numerous and important water power sites. It is anticipated that electric operation will effect a saving in the cost of power

TABLE CCXXIX. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF AMERICAN STEAM ROAD ELECTRIFICATIONS
CLASS IV—TUNNEL OPERATION

Details	Baltimore & Ohio Railroad	Grand Trunk Railway	Great Northern Railway	Michigan Central Railroad	Boston & Maine Railroad
1	2	3	4	5	6
General:					
System of traction	Low tension direct current	Single-phase alternating current	Three-phase alternating current	Low tension direct current	Single-phase alternating current
Conductors:					
Type of working conductors	Third rail	Overhead trolley	Overhead trolley	Third rail	Overhead trolley
Position	Over running	22 ft. above track	22 ft., 6 in., above track	Under running	22 ft. above track
Size and material	Steel 75—100 lb. per yd.	Copper 0.46 in. equiv. diam.	Copper 0.46 in. equiv. diam.	Special steel 70 lb. per yd.	Phono-electric 0.46 in. equiv. diam.
Type of collector	Vertical "T" shaped shoe	Pantograph sliding	Wheel trolley	Cast iron under contact shoe	Pantograph sliding.
Transmission voltage	None	None	33,000, 3-phase	None	11,000, single-phase
Contact voltage	650 d. c.	3,300 single-phase	6,600, 3-phase	650 d. c.	11,000, single-phase
Power Generation:					
Owner of plant	Railroad Company	Railroad Company	Railroad Company	Purchased from Detroit Edison Company	Railroad Company.
Number of plants and type	One steam-electric	One steam-electric	One hydro-electric		One steam-electric
Location	Baltimore near Camden Station*	Port Huron	2.5 miles west of Leavenworth	Detroit	2.5 miles south of west portal tunnel
Plant capacity (total, 1-hr. rating)	2,500 kw.	2,500 kv-a.	6,000 kv-a.	840 kw.	6,000 kv-a.
Number of generators (total)	5	2	3	None	2
Rating and type	500 kw., 500 v. d.c.	1,250 kw., 3,300 v., 3-phase, 25-cycle	2,000 kw., 6,600 v., 3-phase, 25-cycle	A.C. at 4,400 v.	3,000 kw., 11,000 v., 3-phase, 25-cycle.
Type of prime mover	Steam engines	Steam turbines	Hydraulic turbines	None	Steam turbines
Number of boilers (total)	13	4	None	None	6
Type	Water-tube	Water-tube	None	None	Water-tube
Rating	250 b.h.p.	400 b.h.p.	None	None	500 b.h.p.
Transmission:					
Feeders (circuit miles)—					
On poles (bare wire)	None	None	64	None	4.84
Underground (insulated cable)	None	None	None	None	None
Type	None	None	3-phase, 25-cycle	3-phase, 60-cycle	Single-phase, 25-cycle 11,000 a. c.
Voltage		None	33,000 a. c.	4,400 a. c.	
Substations:					
Number and type	One rotary	None	One static	One motor-generator	None
Average distance apart	None	None	None	None	None
Capacity (total)	3,000 kw.	None	2,550 kw.	2,000 kw.	None
Size of rotary converter units	1,000 kw.	None	None	1,000-kw. (motor-generator)	None
Size of transformer units	1,100 kv-a.	None	850 kv-a.	None	None
Rolling Stock:					
Locomotives or motor cars used	Locomotives	Locomotives	Locomotives	Locomotives	Locomotives
Number and service	4 combined pass. and frt.; 5 frt.	6 combined pass. and frt.	4 combined pass. and frt.	6 combined pass. and frt.	5 combined pass. and frt.
Train weight (average) excluding locomotive (tons, 2,000 lb.)	466 tons combined pass. and frt., 1,570 tons, freight †	1,000 tons, freight,‡ 150-600 tons, passenger	1,500 tons, freight,¶ 675 tons, passenger	800 tons, freight, 310 tons, passenger	1,600 tons, freight, 500 tons, passenger
Locomotives:					
Class	0-4-4-0 (combined pass. and frt.) 0-4-4-0 (combined pass. and frt.) 0-8-0 (freight)	0-6-0	0-4-4-0	0-4-4-0	2-4-4-2
Total weight (tons, 2,000 lb.)	100 (combined pass. and frt.) 90 (combined pass. and frt.) 80 (freight)	65.75	115	100	130
Weight on drivers (lb.)	200,000 (combined pass. and frt.) 180,000 (combined pass. and frt.) 160,000 (freight)	131,500	230,000	200,000	192,000
Number of motors	4	3	4	4	4
Type of motor	Geared to axle	Geared to axle	Double geared to axle	Geared to axle	Geared to quill spring drive
Capacity per motor (h.p., 1-hr. rating)	275 (combined pass. and frt.) 275 (combined pass. and frt.) 200 (freight)	225	475	280	375
Tractive effort of locomotive (lb., 1-hr. rating)	26,000 (combined pass. and frt.) 35,000 (freight)	19,000	46,000	35,000	
Normal speed of locomotive (full load on level track), mi. per hr.	35§ 10**	35	15	35	30

* Power partly purchased and delivered through 3,000-kw. rotary converter substation.

† 3-80 ton or 2-100 ton units for freight; weight excluding trailing steam locomotive.

§ Combined passenger and freight locomotives.

** Freight locomotives.

‡ Requires two locomotives for freight.

¶ Requires three locomotives for freight trains and two locomotives for passenger trains.

and an increase in speed and track capacity on the heavy mountain grades. In the initial electrification both freight and passenger trains are to be operated by electric locomotives. Freight trains are to have a maximum trailing load of 2,500 tons and will be operated at a speed of about 15 miles an hour against 2.0 per cent grades. Passenger trains are to have a maximum trailing load of 800 tons and will be operated at a speed of about 24 miles an hour against 2.0 per cent grades. Estimates are based upon a total daily freight traffic of 20,000 tons and a passenger traffic of six trains. It is understood that the electric system will employ direct current at 3,000 volts with an overhead catenary trolley wire. Work upon this installation was begun in the summer of 1914.

ENGLISH RAILROAD ELECTRIFICATIONS

205.23 Character of Electrifications in England: There are a number of instances of electric traction on English trunk line railroads. In all cases the installation involves a limited length of line and the operation includes suburban passenger service only. No through passenger or long distance freight trains are electrically operated. In a few instances, a limited amount of local freight traffic is conducted electrically.

The initial electric installation in England was completed in 1903 on the Mersey Tunnel Railway at Liverpool. During the following five or six years other installations were made on four of the trunk line railroads. In 1909 a portion of the important suburban electrification on the London, Brighton & South Coast Railway was completed, and extensions were made in the two succeeding years. During 1913 three projects for the electrification of suburban lines of important trunk railroads in and around London were inaugurated. These installations, when completed, will form the greatest extent of electrified trackage in England. They have been undertaken in order to relieve congestion in the terminal stations by the substitution of motor cars for locomotive trains, and in some cases to relieve the main lines in the city of a portion of the heavy suburban traffic by forming connections in the suburbs with the underground railroad lines. Since the underground railroads will provide service reaching all central parts of London, the trunk railroads expect incidentally to recover a considerable short haul suburban business which of late years has been diverted to the tram lines and motor busses. As these electrified trunk railroad services will operate over existing underground electric lines, the rolling equipment adopted has been made interchangeable with that of the city lines. The traction systems will also be the same as those employed by the city lines.

205.24 Class A — Trunk Line Railroads — North Eastern Railway: The electrified portion of the North Eastern Railway consists of a network of lines extending out from Newcastle-on-Tyne. Newcastle is situated on the north bank of the River Tyne, about eight miles from the mouth of the river. The territory on both sides of the river from the city to the sea is occupied by a succession of ship-building yards and industrial plants and has a large population. Situated on the north side of the river are Tynemouth and Whitley Bay, which are extensive residential districts and holiday resorts. The passenger traffic between Newcastle and the coast is therefore large and a considerable portion of it is constant at all seasons of the year. During the holiday periods the traffic is augmented for short periods and often amounts to more than 100,000 passengers daily.

The electrification of this line was one of the earliest in England, and was undertaken largely as an experiment to determine the economic possibilities of electric traction and to retain, by means of a more frequent and rapid train service, the passenger traffic which was being diverted to the growing system of electric tramways in the territory served.

Passenger service is conducted by multiple-unit trains composed of motor and trailer cars. During rush hours these trains are dispatched at short intervals. The cars are new and of the American, or open corridor, type, with a seating capacity of 60 passengers per car. A certain amount of freight traffic is handled electrically by 56-ton locomotives and motor baggage cars, but this electric freight service is not extensive. The motor baggage cars handle express matter on the main electrified section, while the locomotives are engaged principally in shifting freight on the Quayside Branch to Manors Station up a tunnel grade of 3.7 per cent. On the other electrified lines of the railroad freight is still handled by steam locomotives.

At the time the electrification was undertaken the only system which had been developed for practical operation was the direct current third rail electric system, which was therefore adopted for this line. Power is purchased from the Newcastle-on-Tyne Electric Supply Company, in the form of three-phase alternating current at 5,500 volts, and is transmitted to substations along the line, where it is converted into 600-volt direct current for distribution to the third rail. Motor cars are equipped with two motors, each of 150-horse-power nominal rating, and are operated in trains with trailer cars. Freight locomotives are of the double-truck type and are equipped with four motors, each of 100-horse-power capacity.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION, JULY, 1904

MILEAGE	
Total route miles	29.5
Total track miles	75.0
TRAIN SERVICE	
Passenger	Motor cars
Freight (shifting)	Locomotives
ELECTRIC TRAIN EQUIPMENT	
Freight locomotives	2
Motor cars	65
Trailer cars	44

The accompanying map, fig. 460, shows the location of the electrified lines of the North Eastern Railway.

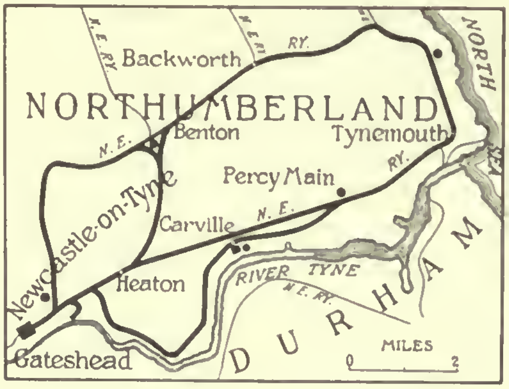

FIG. 460. ELECTRIFIED LINES OF THE NORTH EASTERN RAILWAY

205.25 Class A—Trunk Line Railroads—Lancashire & Yorkshire Railway: The electrified portion of the Lancashire & Yorkshire Railway consists of two suburban branch lines, one extending from Liverpool to Crossens through Southport, and the other from Liverpool to Ormskirk through Aintree. Connection is made with the Liverpool Overhead Railway at Seaforth to provide for continuous service into Liverpool. The Southport Branch, which is 18.5 miles in length, runs along the sea coast through a residential district, and for a distance of about 4.5 miles out of Liverpool it parallels an extensive system of docks near which are located several large freight stations. The Southport Branch was electrified in 1904, and in 1906, when the Aintree Branch was opened, arrangements were made with the Liverpool Overhead Railway for the operation of through trains from Dingle to Crossens and Aintree. On this latter extension a large passenger business is handled in connection with the annual race meets.

The purpose of this electrification was to provide a service which would meet the competition of the electric tramways and relieve congestion due to the switching movements of the steam locomotives at the terminals. It was believed that by operating a more frequent service and by furnishing a more rapid schedule, the traffic which had been lost to the tramways could be regained, and that by the use of motor car trains the congestion at the terminal station could be relieved. The electrification has resulted in an increase of local traffic at Liverpool. The number of trains now operated is double that previously handled in steam service. All this has been attained without any increase in the terminal station trackage.

The freight traffic is still handled by steam locomotives but passenger service is entirely electric. The speed of the electric express trains is the same as that which was maintained during steam operation, 44.5 miles an hour, but the speed of local trains has been increased under electric operation from 20 to 30 miles per hour including stops, thereby providing one of the most rapid suburban services in the world. The trains are operated on the multiple-unit plan with motor and trailer cars. The cars are of the open corridor type. Trains are normally composed of from three to five cars, of which two are motor cars.

The system adopted in this early example of electrification employs direct current at 600 volts with third rail conductor and fourth rail return. Power is generated in a steam power plant at Formby, owned and operated by the railroad, as three-phase, 25-cycle, alternating current at 7,500 volts and is transmitted to six substations along the line. The current is transformed and converted by rotary converters into direct current at the proper voltage and fed into the conductor rails. It was found that the nature of the traffic caused heavy fluctuations in the power requirements, and to overcome this factor buffer battery plants were installed along the line and in some of the substations.

General characteristics of this electrification are:

DATE OF INITIAL ELECTRIC OPERATION

Liverpool (Exchange Station) to Crossens	March, 1904
Liverpool (Dingle) to Crossens via Liverpool Overhead Railway	Jan., 1906
Seaforth and Bankhall to Aintree	Oct., 1906
Aintree to Maghull	Oct., 1906
Maghull to Town Green	March, 1911
Town Green to Ormskirk	May, 1913

MILEAGE

Total route miles	37.25
Total track miles	91.00

TRAIN SERVICE

Passenger	Motor cars

AVERAGE NUMBER OF CARS PER TRAIN

Passenger	3.96

AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)

Passenger	440

ELECTRIC TRAIN EQUIPMENT

Motor cars	70
Trailer cars	84

TRAIN-MILES PER ANNUM (1913)

Passenger	1,730,000

CAR-MILES PER ANNUM (1913)

Passenger	6,854,000

TRACTION POWER REQUIREMENTS (1913)

Maximum load, kw.	7,000
Total per annum, kw-hr.	28,000,000

The accompanying map, fig. 461, shows the location of the electrified lines of the Lancashire & Yorkshire Railway.

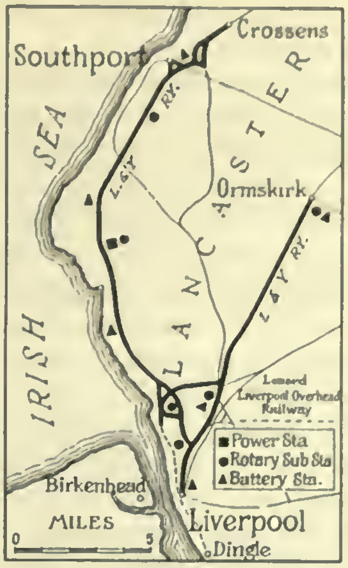

FIG. 461. ELECTRIFIED LINES OF THE LANCASHIRE & YORKSHIRE RAILWAY

205.26 Class A—Trunk Line Railroads—Great Western Railway: The Great Western Railway is one of the important trunk line systems in the south and west of England. It serves principally points on the Bristol Channel and in all parts of Devon and Cornwall. Its main terminus is at Paddington Station, London, but it also has trackage rights over a portion of the Inner Circle Railway from Bishops Road to Aldgate. The Hammersmith & City Railway, which is jointly owned by the Great Western and the Metropolitan Companies, connects with the main line of the Great Western at Westbourne Park Station. The electrified portion of the Great Western Railway comprises only the short stretch of its main line between Bishops Road and Westbourne Park, 1.75 miles. This, with the jointly owned Hammersmith & City Railway from Westbourne Park to Hammersmith, provides 4.1 miles of electrified route. No extensions of main line electrification are in contemplation, but in connection with one of the latest extensions of the city subway and tube railroads, it is proposed that the Great Western Railway equip for electric operation a short stretch of track from Wood Lane to Ealing, over which trains are to be operated by the Central London Railway. Electric current for the operation of this line is to be supplied by the Great Western Railway. Any Great Western trains, however, which may be operated over the line will, under the present plan, be operated by steam as heretofore.

The electrification of the Great Western Railway line from Bishops Road to Westbourne Park was incidental to that of the Hammersmith & City Railway lines, and was required shortly after the electrification of the Metropolitan

Railway to provide for operation of local service through a city tunnel line.

The Metropolitan Railway Act of 1898, by which electrification of the Metropolitan lines was authorized, stated that it was expedient to provide for an improvement in the ventilation of the railroad. The Metropolitan Railway is one of the city subway lines operating over the Inner Circle and over lines extending to suburban points. There is no doubt that the conversion of this railroad from steam to electric operation had become a public necessity, owing to the smoke and fumes in the tunnel. Since the trains on the Hammersmith & City Railway operate over the line of the Metropolitan Railway, it was suggested by the latter road and concurred in by the Great Western that the Hammersmith & City Railway be adapted for operation by electric power concurrently with the adoption of electric operation on the Inner Circle Railway, thus making it possible to handle continuous passenger traffic over the two railroads forming the through route to the city. It was thought also that this plan might be the means of revivifying the Hammersmith & City Railway line. The electrification of the Hammersmith & City Railway was accordingly authorized by the Metropolitan Railway Act of 1902, and electric operation began in November, 1906. The electrification of the Great Western from Bishops Road to Westbourne Park followed that of the Hammersmith & City Railway.

Electric operation by motor car trains embraces a joint suburban passenger service. The motor cars are of the corridor type and are operated on the usual multiple-unit plan.

The 600-volt, direct current, third rail system is employed. Power is generated in the power station of the Great Western Railway at Park Royal, as three-phase alternating current at 6,600 volts and is transmitted to three substations along the line. The current is converted by motor-generator sets. The tracks are equipped with a negative or "return" rail placed between the track rails. This return rail is employed by nearly all the London railroads operated by the direct current system and is intended to dispose of stray currents which find their way into the earth where the track rails are used for the return circuit.

The technical results of this electrification have been satisfactory, but owing to the limited business on this line, the financial results of the undertaking have been disappointing.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION, NOV., 1906	
MILEAGE	
Total route miles	4.1
Total track miles	9.6
TRAIN SERVICE	
Passenger	Motor cars
AVERAGE NUMBER OF CARS PER TRAIN	
Passenger	4.08
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)	
Passenger	560
ELECTRIC TRAIN EQUIPMENT	
Motor cars	40
Trailer cars	80
TRAIN-MILES PER ANNUM (1913)	
Passenger	619,400
CAR-MILES PER ANNUM (1913)	
Passenger	2,528,000
TRACTION POWER REQUIREMENTS (1913)	
Maximum load, kw.	4,000
Total per year, kw-hr.	8,000,000

The accompanying map, fig. 462, shows the location of the electrified lines of the Great Western Railway.

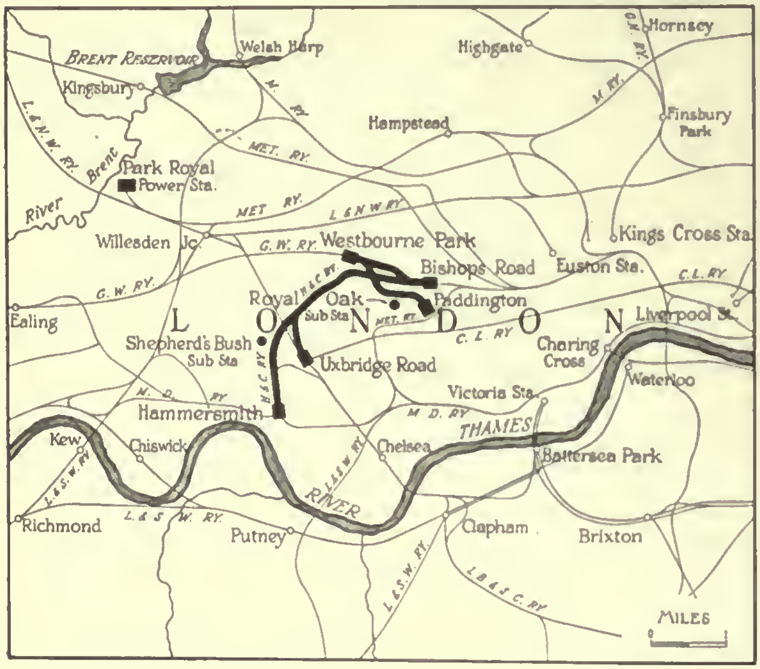

FIG. 462. ELECTRIFIED LINES OF THE GREAT WESTERN RAILWAY

205.27 Class A — Trunk Line Railroads — Midland Railway: The electrified section of the Midland Railway consists of a double track branch line about nine miles long, known as the Heysham-Lancaster line. This line conducts a heavy local passenger traffic between Lancaster and the seashore at Heysham and Morecambe. Connection is made in Lancaster between the Midland Railway at Green Ayre Station and the London & Northwestern Railway at Castle Station, by electric shuttle service.

The electrification was largely of an experimental character, its purpose being to determine the proper system for future electrification of the main line and to assist in relieving terminal congestion. The choice of this section of the road for the experiment was based on the fact that there existed at Heysham a power station which could be enlarged at small cost to accommodate the generating machinery, and also on the circumstance that summer traffic was very heavy and the terminal was often congested because of the slow average speed of the steam trains and the difficulty of switching steam locomotives.

The electric operation includes passenger traffic only. Motor car trains are used and about 80 trains per day are operated over different portions of the line. The cars are of the open corridor type, seating 72 passengers each.

This was the first example of the use of single-phase alternating current traction in England. Power is generated as direct current at 460 volts in a steam power plant located at Heysham and owned by the railroad. It is converted by means of motor-generator sets into single-phase alternating current at 6,600 volts and fed into the overhead working conductor. The trains are light, consisting usually of one motor car and two trailers. Each motor car is equipped with two single-phase motors of either 150 or 210 horse-power capacity. The operation of this experimental line has been carefully observed. Both operating and maintenance results are regarded as satisfactory.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION, APRIL, 1908

MILEAGE	
Total route miles	9.25
Total track miles	19.40

TRAIN SERVICE	
Passenger	Motor cars

AVERAGE NUMBER OF CARS PER TRAIN	
Passenger	2.44

AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)	
Passenger	80

ELECTRIC TRAIN EQUIPMENT	
Motor cars	3
Trailer cars	6

TRAIN-MILES PER ANNUM (1913)	
Passenger	92,740

CAR-MILES PER ANNUM (1913)	
Passenger	226,680

TRACTION POWER REQUIREMENTS (1913)	
Maximum load, kw. (approximate)	300
Total per year, kw-hr.	300,000

The accompanying map, fig. 463, shows the location of the electrified lines of the Midland Railway.

FIG. 463. ELECTRIFIED LINES OF THE MIDLAND RAILWAY

205.28 Class A — Trunk Line Railroads — London, Brighton & South Coast Railway: The London, Brighton & South Coast Railway is one of the more important of the shorter railroad systems of England. It serves a densely populated territory lying south and east of London and extends to cities on the English Channel. This road, with a total of 454 miles, does a gross business of $17,600,000 per year, of which $12,840,000 is revenue from passenger traffic. The lines form a compact network, and almost the entire system lies within the suburban areas of the large cities or towns. The main line from London to Brighton and Eastbourne is 66 miles in length and has a traffic of over 60 passenger trains daily in each direction. For a distance of 20 miles out of London the commuter or suburban business is very heavy. The excursion business conducted at the Brighton end of the line is also heavy. The number of passengers for 1913, including those using season tickets, was over 20,000,000. In 1905 the company determined to electrify for local traffic a short line called the "South London

Elevated," which forms a loop between two of the main stations in London, namely, Victoria and London Bridge. Contracts were let in 1906, and electric operation began in 1909. The line is 8.7 miles in length and passes through a densely populated portion of the city and its suburbs. The satisfactory results of this operation led the company, in 1910, to undertake the electrification of a similar line from Battersea Park and Peckham Rye to Crystal Palace. This extension was opened in 1911 and added 13.6 route miles to the electric system. Recently, further extension of the electrification was undertaken to Coulsdon on the Brighton line and to Cheam on the Horsham line, thus equipping for electric operation the entire suburban system out of London.

The purpose of the electrification was to relieve the congestion of traffic and to obtain high speed over lines with numerous grades. It was found also that Victoria Station was becoming congested and that an expenditure of $15,000,000 or more would be necessary to provide additional terminal facilities through physical enlargement. It was considered wise, therefore, to expend money upon electrification rather than upon physical enlargement, especially since electrification promised to increase the traffic. Another reason which led to electrification was the fact that a large decrease in suburban traffic over the steam road was resulting from improvements in service out of London, such as the electrification of tramways, the use of motor busses and the electrification of underground railroads, and it was foreseen that this class of competition would increase. In the year 1902, before the opening of the London County Council tramways, 1,213,281 tickets were sold at one station (Peckham Rye), while in the year 1909 the sales at this station fell to 526,373 tickets. The total number of passengers carried in 1902 was nearly 8,000,000, while in 1909 the number had decreased to less than 4,000,000.

FIG. 464. ELECTRIFIED LINES OF THE LONDON, BRIGHTON & SOUTH COAST RAILWAY

Under electric operation the average speed on the South Side line has been increased from 15 to 22 miles an hour, and the number of trains handled at Victoria Station has been increased from 456 to 739 a day. At the London Bridge Station the number of trains has been increased from 613 to 901 a day. To further attract business, fares have been reduced, and the combination of fast service and low fares has resulted in the recovery of the business which had been lost as a result of electric tram competition. The railroad reports that both financial and technical results of this suburban electrification have been satisfactory, and the decision has been made to extend the electrification to handle the entire suburban system.

Electric operation includes passenger service only. Multiple-unit trains of motor and trailer cars are used. The maximum train is composed of six cars. Each motor car is equipped with four single-phase motors. Single-phase alternating current with the overhead catenary contact system is used. Single-phase current at 6,700 volts is purchased from the London Electric Supply Corporation and is distributed to the contact system at the same voltage.

The accompanying map, fig. 464, shows the location of the electrified lines of the London, Brighton & South Coast Railway.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION	
Victoria to London Bridge	Dec., 1909
Battersea Park to Selhurst	May, 1911
Peckham Rye to Tulse Hill	May, 1912
MILEAGE	
Total route miles	22.3
Total track miles	70.7
TRAIN SERVICE	
Passenger	Motor cars
AVERAGE NUMBER OF CARS PER TRAIN	
Passenger	4.25
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)[*]	
Passenger — Victoria Station	739
Passenger — London Bridge Station	901
ELECTRIC TRAIN EQUIPMENT	
Motor cars	50
Trailer cars	82
TRAIN-MILES PER ANNUM (1913)	
Passenger	1,409,000
CAR-MILES PER ANNUM (1913)	
Passenger	5,980,000
TRACTION POWER REQUIREMENTS (1913)	
Maximum load, kw.	7,500
Total per annum, kw-hr.	17,400,000[†]

205.29 Class A—Trunk Line Railroads—Technical Characteristics: Table CCXXX presents a summary of the general and technical characteristics of electrifications of English steam roads included in Class A—Trunk Line Railroads.

205.30 Class B—Secondary Railroads—Mersey Railway: The wide estuary of the River Mersey separates the city of Liverpool from Birkenhead and the Cheshire peninsula lying to the west. The feasibility of building a tunnel under the Mersey to provide rail communication between the populous districts on the river banks had long been discussed and the work was finally undertaken in the year 1879. The tunnel railroad was opened for traffic in 1886. Later it was extended in both Liverpool and Birkenhead and brought into direct connection with the long distance main lines terminating in these cities. At the time of this tunnel construction electric traction was unknown and the tunnel was accordingly made of large size, 26 feet wide and 19 feet high, for the accommodation of steam locomotive trains on a double track railroad. In order to maintain proper ventilation a smaller auxiliary tunnel was driven parallel to the river tunnel and an elaborate ventilating system with exhaust fans was installed. To provide adequate drainage for the main tunnel, a tunnel was constructed to drain the rock outside the main tunnel and to handle the seepage water within the main tunnel. About 6,000 gallons per minute are pumped from this drainage system by means of heavy, slow acting beam pumps installed in plants at each end of the tunnel. These drainage and ventilating systems had an important bearing on the adoption of electric traction at a later date. The Mersey Railway is 4.75 miles long. Located on the line are seven passenger stations, all of which are entirely or partly underground at depths of from 20 to 100 feet. The grades are heavy toward the center of the river, the maximum being 3.7 per cent.

From 1886, the date of its initial operation, until 1903 the line was operated by steam locomotives. A heavy passenger traffic was conducted, but it was not profitable because of the high operating costs. The elaborate ventilating system did not serve to remove the objectionable gases, and the journey was much disliked by the public. The river ferries competed actively for business and the tunnel traffic increased very slowly. Serious items of expense incident to operation were incurred in providing ventilation, in maintaining hydraulic lifts at two of the stations and in operating the steam pumps used for the removal of drainage water. It was estimated that electric operation would greatly decrease the cost of ventilation, and it was thought that the improved atmospheric conditions as well as the more rapid schedule made possible by electric traction would largely increase the traffic. In 1903, just before the inauguration of electric operation, the number of passengers carried was 6,700,000; in 1912, under electric operation, the number carried was 15,819,000. With the introduction of electric operation, the large ventilating plants were discarded and small electric fans were substituted. This change effected a saving in ventilating costs of $26,000 per year. Electrically driven pumps were also substituted for the steam driven pumps which operated the hydraulic lifts.

Passenger trains are made up of motor and trailer cars. A five-minute schedule is maintained for about twelve hours daily and a three-minute schedule for seven hours. About 255 trains in each direction are operated on the line

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[*] Includes a large number of shuttle trains on the South London line between Victoria and London Bridge.

[†] Includes electric power for repair shops.

TABLE CCXXX. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF ENGLISH STEAM RAILROAD ELECTRIFICATIONS. CLASS A—TRUNK LINE RAILROADS

Details	North Eastern Railway	Lancashire & Yorkshire Railway	Great Western Railway	Midland Railway	London, Brighton & South Coast Railway
1	2	3	4	5	6
General:					
System of traction	Low tension direct current.	Low tension direct current	Low tension direct current	Single-phase alternating current	Single-phase alternating current
Conductors:					
Type of working conductor	Third rail	Third rail (4th rail return)	Third rail (4th rail return)	Overhead trolley	Overhead trolley
Position	Over running	Over running	Over running	18 ft., 3 in., max., 13 ft., 3 in., min. above track	16 ft., 0 in., above track
Size and material	Steel rail, 80 lb. per yd.	Steel rail, 70 lb. per yd.	Steel rail, 103 lb. per yd.	Copper 0.37 in. equiv. diam.	Copper 0.50 in. equiv. diam.
Type of collector	Cast iron, link shoe.	Cast steel, link shoe	Shoe	Pantograph and sliding bow trolley	Sliding bow trolley with double contacts
Transmission voltage	5,750, 3-phase	7,500, 3-phase	6,600, 3-phase	None	6,700, 3-phase
Contact voltage	600, direct	600, direct	600, direct	6,600, single-phase	6,700, single-phase.
Power Generation:					
Owner of plant	Purchased from Newcastle Electric Supply Company	Railway Company	Railway Company.	Railway Company	Purchased from London Electric Supply Corporat'n
Number of plants and type	1 steam-electric	1 steam-electric	1 steam-electric	1 gas-electric	1 steam-electric
Location	Carville	Formby	Park Royal	Heysham	Deptford, Southeast London
Plant capacity (total, 1-hr. rating)		13,250 kv-a.	6,000 kv-a	700 kw.	7,500 kv-a
Number of generators (total)	None	7	8	4	None
Rating and type	A.C. at 5,750 v.	4-1,500 kw., 1-750 kw., 1-4,000 kw., 1-2,500 kw., 750 v'lt, 3-phase, 25-cycle.	750., kw 6,600-v. 25-cycle, 3-phase.	3-150 kw., 1-230 kw. 460-v., d.c.	A.C. at 6,700 v.
Type of prime mover	None	Steam engines and steam turbines	Steam engines	Gas engines	None
Number of boilers (total)	None	16	10	None	None
Type	None	Lancashire	Water-tube	None	None
Rating (b. h. p.)	None	240	575	None	None
Transmission:					
Feeders (circuit miles) —					
On poles (bare wire)	None	23.0	None	None	None
Underground (insulated cable)	None	53	27	None	5 56
Type	3-phase, 40-cycle	3-phase, 25-cycle	3-phase, 25-cycle	None	Single-phase, 25-cycle 6,700 a. c.
Voltage	5,500 a.c.	7,500 a. c	6,600 a.c.	None	
Substations:					
Number and type	5 rotary, 1 in power-station	4 battery, 4 rotary, 2 rotary and battery	2 motor-generator	1 motor-generator in power house	None
Average distance apart (miles)	6	4.7 between rotary.	2.0	None	None
Capacity (total)	11,200 kw.	11,400 kw., 7,200 ampere hours, batteries	4,400 kw.	350 kw	None
Size of rotary converter units	800 kw.	600 kw., (1,200 ampere hr. average, battery)	400 kw., (motor-generator)	2-175 kw., (motor-generator)	None
Size of transformer units	300 kv-a.	200 kv-a.	None	None	None
Rolling Stock:					
Locomotives or motor cars used	Locomotives and motor cars	Motor cars	Motor cars	Motor cars	Motor cars
Number and service	65 motor cars, 44 trailers, 2 locomotives (freight)	70 motor cars, 84 trailer cars	40 motor cars, 80 trailer cars	3 motor cars, 6 trailer cars	50 motor cars, 82 trailer cars
Train weight (average) excluding locomotive (tons, 2,000 lb.)	300	None	None	None	None
Locomotives:					
Class	0-4-4-0	None	None	None	None
Total weight (tons, 2,000 lb.)	56	None	None	None	None
Weight on drivers (lb.)	112,000	None	None	None	None
Number of motors	4.	None	None	None	None
Type of motor	Geared	None	None	None	None
Capacity per motor (h.p., 1-hr. rating)	100	None	None	None	None
Tractive effort of locomotive (pounds, 1-hr. rating)	14,740	None	None	None	None
Normal speed of locomotive (rated load on level track), mi. per hr.	14 3	None	None	None	None
Motor Cars:					
Weight excluding passengers (tons, 2,000 lb.)	33	50.6 (A) 24.2 (B) 73.7 (C)	41.8	41.3 (A) 44.6 (B)	59.4 (A) 62.3 (B)
Seating capacity	60	80 (A) 70 (B) 68 (C)	48	72	66 (A) 70 (B)
Number of motors	2	4 (A) 2 (B) 4 (C)	4	2	4
Capacity per motor (h.p., 1-hr. rating)	150	150 (A) 125 (B) 250 (C)	150	150 (A) 210 (B)	115 (A) 150 (B)
Trailer Cars:					
Weight excluding passengers (tons, 2,000 lb.)		28.6.	27.2	19.3	22.0 (A) 26.4 (B)
Seating capacity	56	66 90 103	56	56	56 (A) 74 (B)

daily. This is more than double the number of steam trains formerly operated and the schedule speed is about 30 per cent greater than that under steam operation.

The direct current, 650-volt, third rail system with fourth rail return is employed. Power as direct current at 650 volts is generated in a centrally located steam power station at Birkenhead and is fed directly into the third rail. A storage battery is used for equalizing the load.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION, MAY, 1903	
MILEAGE	
Total route miles . .	4.75
Total track miles . .	12.25
TRAIN SERVICE	
Passenger	Motor cars
AVERAGE NUMBER OF CARS PER TRAIN	
Passenger	4.87
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)	
Passenger	510
ELECTRIC TRAIN EQUIPMENT	
Motor cars	24
Trailer cars	37
TRAIN-MILES PER ANNUM (1912)	
Passenger	561,494
CAR-MILES PER ANNUM (1912)	
Passenger	2,251,000
TRACTION POWER REQUIREMENTS (1912)	
Maximum peak load, kw.	5,000
Total per annum, kw-hr.	6,200,000

FIG. 465. ELECTRIFIED LINES OF THE MERSEY RAILWAY

The accompanying map, fig. 465, shows the location of the electrified lines of the Mersey Railway.

205.31 Class B — Secondary Railroads — Technical Characteristics: Table CCXXXI presents a summary of the general and technical characteristics of electrifications of English steam roads included in Class B — Secondary Railroads.

205.32 English Electrification Projects under Construction or in Contemplation: The London & North Western Railway is one of the important trunk lines connecting London with the north and with points on the Irish Sea and Bristol Channel. Its main line terminal in London is the Euston Station near Regent's Park. In addition to delivering passengers at the Euston Station, the road has a connection with the Inner Circle Railway, which is an electrically operated subway line circumscribing the central portion of the city. This connection is over the North Western Company's line from Willesden Junction to Earls Court, from which point the road has running rights over the Inner Circle Railway (Metropolitan District Railway) to Mansion House in the city. The electrification will include the new relief line for suburban service parallel to the main line from Euston to Watford which is now under construction, the North London Railway from Broad Street Station, the line from Camden Town via Hampstead to Willesden High Level, thence to Earls Court, and a connection with the Baker Street and Waterloo Railway (tube) at Queens Park. The objects of this electrification are to relieve the main line of a portion of the heavy suburban traffic which comes into Euston Station and to effect an increase in suburban business by frequent and rapid train service connecting directly with the city subway and tube systems. Electric service is to be conducted by motor car trains equipped for operation over the electrified city subway system, and that portion of the traffic handled in connection with the tube railroad system is to be conducted by

TABLE CCXXXI. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF ENGLISH STEAM RAILROAD ELECTRIFICATIONS, CLASS B—SECONDARY RAILROADS

Details	Mersey Railway
General:	
System of traction	Low tension direct current
Conductors:	
Type of working conductor	Third rail (4th rail return)
Position	Over running
Size and material	100 lb. per yd., 60 lb. per yd.
Type of collector	Link shoe
Transmission voltage	None
Contact voltage	650 direct
Power Generation:	
Owner of plant	Railway Company
Number of plants and type	1 steam-electric
Location	Shore Road — Birkenhead
Plant capacity (total, 1-hr. rating)	4,400 kw.
Number of generators (total)	4
Rating and type	1,200 kw. 800 kw. 650 v. d. c.
Type of prime mover	Steam engines Steam turbine
Number of boilers (total)	9
Type	Water-tube
Rating (b. h. p.)	550
High Tension Transmission:	
Feeders (circuit miles)—	
On poles (bare wire)	None
Underground (insulated cable)	None
Type	None
Voltage	None
Substations:	
Number and type	None
Average distance apart	None
Capacity (total)	None
Size of rotary converter units	None
Size of transformer units	None
Rolling Stock:	
Locomotives or motor cars used	Motor cars
Number and service	24 motor cars, 37 trailer cars
Train weight (average), including locomotive (tons, 2,000 lb.)	None
Locomotives:	
Class	None
Total weight (tons)	None
Weight on drivers (lb.)	None
Number of motors	None
Type of motor	None
Capacity per motor (h.p., 1-hr. rating)	None
Tractive effort of locomotive (lb., 1-hr. rating)	None
Normal speed of locomotive (rated load on level track), mi. per hr.	None
Motor Cars:	
Weight excluding passengers, (tons, 2,000 lb.)	40.5
Seating capacity	46–50
Number of motors	4
Capacity per motor (h. p., 1-hr. rating)	100
Trailer Cars:	
Weight excluding passengers (tons, 2,000 lb.)	22
Seating capacity	56–64

cars of small cross-section similar to those employed in the tubes. The 600-volt direct current third rail system of traction, interchangeable with that used on the lines with which it connects, will be used. A steam power station with a capacity of 25,000 kilowatts is to be erected by the London & North Western Railway near Wembley. Power will be generated as three-phase, 25-cycle, alternating current at 11,000 volts and transmitted to substations along the lines. The substations are to be equipped with storage batteries. This electrification will embrace 79 miles of track, and the initial electric equipment will consist of 100 motor cars.

The London & South Western Railway, one of the important trunk line systems serving the country southwest of London and extending to Southampton and ports on the English Channel and to Plymouth and west coast resorts in Cornwall and Devon, purposes to electrify a network of suburban lines for a total distance of about 100 miles. The initial installation, now under construction, will embrace the loop line from Waterloo Station, London, to Kensington and return, and the line from Point Pleasant to Wimbledon, a total distance of 30.5 miles. Included in this mileage are tracks to Wimbledon and Richmond, which have been electrified for the operation of the Metropolitan District Railway's electric trains from the Inner Circle Railway. The object of the extensive electrification proposed by the London & South Western Railway is to provide a service sufficiently frequent and rapid to recover the suburban and local traffic which has been diverted to the city electric lines and motor busses. Only local passenger traffic is to be operated electrically. Freight traffic, and passenger traffic originating beyond the electrified zone, are to be handled by steam over the electrified lines. The motor cars, of which 168 will be required, are to be of the compartment type providing seating capacity for 60 persons. The motor cars will weigh about 38 tons each and are to be equipped with two 275-horse-power motors. The trailer cars are to be of the same general design as the motor cars, but will seat 70 persons and weigh 26 tons. The standard train will weigh about 115 tons loaded and will consist of two motor cars and one trailer car. The schedule speed will be about 25 miles an hour, with stops about 1.5 miles apart. The third rail, 600-volt, direct current system has been adopted because of its general use on London lines which conduct joint service. A centrally located power plant is now under construction at Wimbledon. The initial equipment will consist of five 5,000-kilowatt, 25-cycle, 11,000-volt, three-phase turbo-generators. High tension current is to be transmitted to nine substations along the lines, at which points it will be transformed and converted to 600-volt direct current and fed to the third rails. The substations are to be about 4.25

miles apart and will be equipped with 1,250-kilowatt or 1,875-kilowatt rotary converter units.

FRENCH RAILROAD ELECTRIFICATIONS

205.33 Character of Electrifications in France: Two French trunk line railroads have electrified sections, but of short length only. Following the electrification of the new terminal of the Orleans Railway in Paris in the year 1900, no heavy electric traction was inaugurated in France until the extensive plans of the Midi Railway were formulated and carried out in an experimental way by the electrification of two disconnected sections in the years 1910 and 1914 respectively. The Orleans Railway installation is a terminal electrification occasioned by the requirements of operation in a tunnel in the city of Paris, and the Midi electrification was rendered desirable because of heavy grade operation in the Pyrenees Mountains. The latter railroad utilizes water power for the production of energy.

In addition to these trunk line installations, there are, in different portions of the country, a number of electric interurban railroads, some of which are of considerable length. Most of them, however, are narrow gage roads and employ light motor cars in their operation. A number of these roads have been electrified with the assistance of the government, which has contributed a portion of the capital required or has aided in the physical construction.

The electric system used on these interurban roads is generally the familiar overhead trolley with direct current at 650 volts. In lines of considerable length, the single-phase, alternating current high tension trolley system is employed.

205.34 Class A—Trunk Line Railroads—Orleans Railway: The Orleans Railway, one of the great trunk line systems of France, has its main terminus at Paris and extends south to Toulouse, a distance of about 425 miles. It is also the direct line from Paris to Bordeaux and the western coast of France. Until the year 1900 its terminus in Paris was at the Austerlitz station, which is situated at a considerable distance from the central portion of the city. When the International Exposition of 1900 opened, a new main station on the Quai d'Orsay near the Champs de Mars was opened, and a 2.5 mile underground terminal railroad connecting the old and the new stations was placed in operation. Electrification of this terminal railroad constituted the initial installation. In 1904, the electric system was extended to Juvisy, a suburban point.

The Quai d'Orsay station has its tracks below the street surface and is reached from the Austerlitz terminus by a double track subway line along the bank of the River Seine. It was necessary, therefore, to use some power other than steam for operating the trains on this section and in the station. The principal object of the Juvisy extension, which added to the electrically operated lines some twelve miles of double track, was to stimulate suburban passenger traffic by frequent and rapid service with multiple-unit motor car trains. Two additional tracks, formerly used only for steam operation, are now being electrified from Austerlitz to Juvisy.

Through trains are operated between Quai d'Orsay station and Austerlitz by electric locomotives, the change of motive power being made at Austerlitz. About 170 trains daily are handled in this manner. Local trains consist of motor and trailer cars, and about 70 trains a day are operated between the Quai d'Orsay and Juvisy.

Direct current with third rail contact was the only system of electric traction which at the time (1900) seemed sufficiently developed to insure continuous and successful operation, and this system was accordingly adopted.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION	
Paris (Quai d'Orsay to Austerlitz)	May, 1900
Paris (Austerlitz to Juvisy)	July, 1904
MILEAGE	
Total route miles	14.4
Total track miles	65.0
TRAIN SERVICE	
Passenger, local	Motor cars
Passenger, through	Locomotives
ELECTRIC TRAIN EQUIPMENT	
Passenger locomotives	18
Motor cars	7
TRACTION POWER REQUIREMENTS	
Maximum load, kw.	4,000
Total per annum, kw-hr.	8,000,000

The accompanying map, fig. 466, shows the location of the electrified lines of the Orleans Railway.

FIG. 466. ELECTRIFIED LINES OF THE ORLEANS RAILWAY

205.35 Classes A and B—Trunk Line Railroads and Secondary Railroads—Midi Railway: The Midi Railway is one of the important French railroad systems. It has a network of lines south of Bordeaux and along the Pyrenees from the Bay of Biscay on the west to the Rhone Valley on the east. Service from Paris to points in Spain is conducted over this railroad and the Orleans Railway. Three sections of the Midi have been electrified, a narrow gage line from Villefranche to Bourg-Madame, a distance of about 35 miles, on which the direct current system is used, and two disconnected sections of line aggregating about 79 route miles of normal gage track in the Pyrenees, on which the single-phase alternating current system is employed. As the result of a controversy between the government and the railroad with reference to inductive disturbances in telegraph and telephone lines, the single-phase sections are not at present in operation. Experimental data regarding single-phase electric operation have, however, been obtained from these lines, and apparently no change is contemplated in the program for the adoption of this system on further extensions.

In 1902, the Midi Railway was requested by the government to operate the state lines which were to be constructed in the Pyrenees. These lines involved heavy gradients and sharp curves, which presented many difficulties to steam operation, and a supplementary agreement was made providing for electric operation on the lines which had curves with a radius of less than 186 feet and grades heavier than 3.3 per cent. The state agreed to supply the hydraulic energy required for generating the current and to be responsible for the cost of transmitting and distributing it. The railroad agreed to provide the generating machinery and the traction equipment. Under this arrangement, the direct current line from Villefranche to Bourg-Madame was equipped for electric operation and placed in service in 1910 and 1911.

A second agreement made in 1907 involved projected lines to be constructed in the Central Pyrenees. No government lines, however, have as yet been electrified under this agreement. In anticipation of the electrification of these government lines at an early date, the railroad has equipped continuous sections of its existing lines for electric operation for the purpose of determining by experiments the system of traction best suited to heavy long distance traffic.

The Villefranche-Bourg-Madame line is regarded as belonging to Class B—Secondary Railroads. The line is of narrow gage (3 feet, 3.5 inches) and extends from Villefranche, the terminus of the standard gage railroad from Perpignan, to Bourg-Madame, a distance of about 35 miles. On leaving Villefranche the road traverses the Valley of the Têt as far as Olette, at which point it crosses the mountain ridge and descends to Bourg-Madame, a town situated near the Spanish frontier. The line passes through 18 tunnels averaging 430 feet in length. The grades are exceptionally heavy, the averages on opposite sides of the summit being respectively 3.8 and 1.7 per cent, and the maximums 6.0 and 5.0 per cent.

Passenger traffic and freight traffic on the Villefranche-Bourg-Madame line were handled initially in mixed trains composed of motor and trailer cars with a maximum weight of 132 tons. Traffic increased so rapidly, however, that this arrangement was soon abandoned and separate passenger and freight trains were substituted. Seven passenger trains and two or three freight trains operate daily between Villefranche and Bourg-Madame. Three or four extra ore trains are operated daily between Villefranche and Joncet.

The present rolling stock consists of ten passenger and ten freight motor cars, each equipped with four 50-horse-power motors.

A direct current, 850-volt system with third rail conductor is used on the Villefranche-Bourg-Madame line. In 1903, when this electrification was planned, single-phase motors and collecting devices had not been developed to such an extent as to insure successful operation. The three-phase system was not considered practicable for maintaining the desired schedule speed over the heavy grades. The difficulty of maintaining, for the three-phase system, two overhead conductors insulated from each other was also regarded as serious.

Power is obtained from a plant operated by the railroad at Cassagne, a point about midway between Bourg-Madame and Villefranche. Four 650-kilowatt alternators of the "double current" type, driven by Pelton water wheels, deliver either 850-volt direct current or 600-volt, six-phase, alternating current. The 850-volt direct current is fed into the contact line directly from the power station and the 600-volt, six-phase current is stepped up to 20,000 volts, three-phase, and fed to the contact system through rotary substations along the line.

General statistics of the Villefranche-Bourg-Madame electrification on the Midi Railway are as follows:

DATE OF INITIAL ELECTRIC OPERATION	
Villefranche—Mont Louis	July, 1910
Mont Louis—Bourg-Madame	June, 1911
MILEAGE	
Total route miles	35
Total track miles	41
TRAIN SERVICE	
Passenger	Motor cars
Freight	Motor cars
AVERAGE NUMBER OF CARS PER TRAIN	
Passenger	3
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)	
Passenger	7
Freight	3
ELECTRIC TRAIN EQUIPMENT	
Motor cars, passenger	10
Motor cars, freight	10
TRAIN POWER REQUIREMENTS	
Maximum load, kw.	1,800
Total per annum, kw-hr.	2,500,000

The standard gage electrified lines of the Midi Railway, which are regarded as belonging to Class A—Trunk Line Railroads, include the line from Villefranche to Ille, a distance of about 15 route miles, which was equipped for electric operation in 1911. Later, the electrification was extended for a distance of 14 miles, from Ille to Perpignan, but this section has not been opened for traffic. In the Central Pyrenees a section of line from Pau to Tarbes, a distance of 36.6 miles, including a branch from Lourdes to Pierrefitte, 13 miles, has been electrically equipped but is not yet in operation. This section will form a part of the system of mountain grade government lines to be constructed.

On the electrically operated section from Villefranche to Ille, extensive tests of the alternating current system of traction and of different types of electric locomotives for hauling heavy freight trains have been conducted. In 1913, on account of the inductive effects interfering with the telegraph and telephone lines along the right-of-way, electric operation has been discontinued, pending adjustment between the government and the railroad with reference to the costs of making changes in the telegraph lines.

The single-phase alternating current system, using 12,000 volts on the trolley wires, has been adopted for these main line electrifications. Current is generated in the government hydro-electric plants at 6,000 volts stepped up to 60,000 volts for transmission to substations in which the potential is reduced to the working voltage. The rolling stock consists of both locomotives and motor cars; the locomotives are

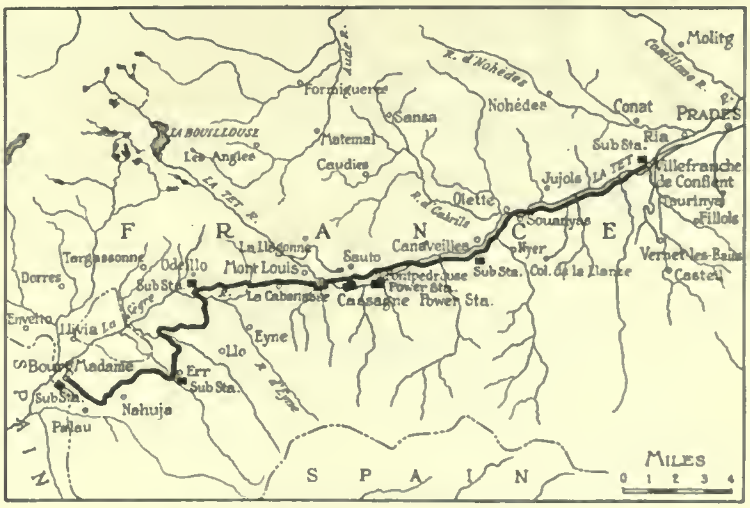

FIG. 467. EASTERN ELECTRIFIED LINES OF THE MIDI RAILWAY

to be used for freight trains and for passenger express trains, while the motor cars will be used for branch line service and for local trains. It is understood that eight 100-ton gearless locomotives and 30 motor cars have been purchased.

The accompanying maps, figs. 467 and 468, show the location of the electrified lines of the Midi Railway.

205.36 Classes A and B—Technical Characteristics: Table CCXXXII presents a summary of the general and technical characteristics of electrifications of French steam roads included in Class A — Trunk Line Railroads and Class B —Secondary Railroads.

GERMAN RAILROAD ELECTRIFICATIONS

205.37 Character of Electrifications in Germany: The three German State Railway Administrations, the Prussian, Baden and Bavarian, became interested as early as 1900 in the possibilities of electric traction. Since that year they have been engaged uninterruptedly in a series of practical experiments to determine the proper system and field of electric operation.

The Prussian Administration first made a trial of direct current, 600-volt, third rail traction on the Wannsee line at Berlin. In 1903 experiments were made with the same system on the Berlin-Grosslichterfelde line. At about this time, the single-phase alternating current system was proposed, and in 1904 the administration decided to introduce this system on the Blankenese-Hamburg-Ohlsdorf line, which was first opened for operation in 1907. These installations were applied in all cases to the operation of city and suburban passenger service. The object was to provide a more frequent and rapid service than had previously been possible under steam locomotive operation, to promote economy by adjusting, in a ready manner, the train lengths to the traffic, and to eliminate locomotive smoke. The interesting Zossen experiments were undertaken at approximately the same time. The technical success of these trial installations led the administration to propose the use of electric traction on trunk railroads, and as a result, the electrification of the Dessau-Bitterfeld section of the Magdeburg-Halle-Leipzig main line was undertaken. When all present plans are completed, the Prussian State Railway will have about 430 miles of line equipped for electric operation and will possess more than 200 electric locomotives and some 300 motor cars.

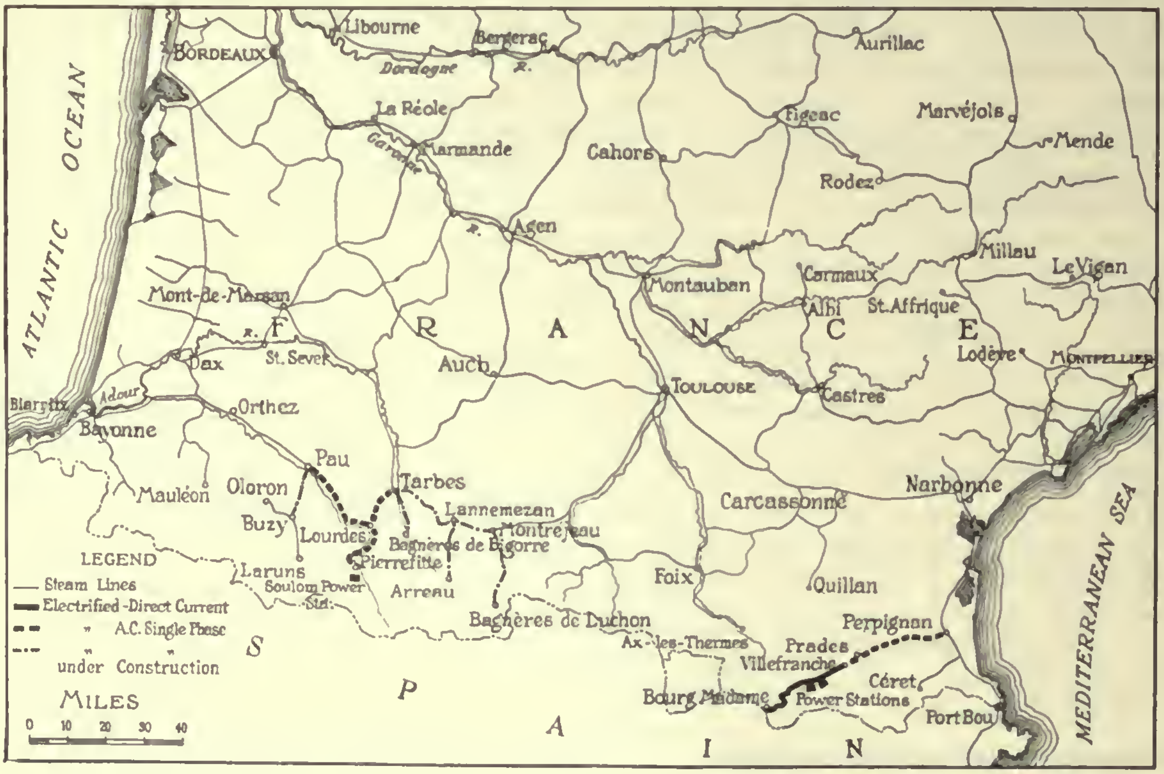

FIG. 468. EASTERN AND WESTERN ELECTRIFIED LINES OF THE MIDI RAILWAY

TABLE CCXXXII. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF FRENCH STEAM RAILROAD ELECTRIFICATIONS, CLASS A — TRUNK LINE RAILROADS, CLASS B — SECONDARY RAILROADS

Details	Orleans Railway Class A	Midi Railway Class B
General:		
System of traction	Low tension direct current	Low tension direct current
Conductors:		
Type of working conductor	Third rail	Third rail
Position	Over running	Over running
Size and material	100 lb. per yd. 2-72 lb. per yd.[*]	Steel 80 lb. per yd.
Type of collector	"L" shaped cast iron and steel	Link shoe
Transmission voltage	5,500, 3-phase	20,000, 3-phase
Contact voltage	600, d. c.	850, d. c.
Power Generation:		
Owner of plant	Railway Company[†]	Railway Company
Number of plants and type	1 steam-electric	1 hydro-electric[‡]
Location	Ivry	La Cassagne
Plant capacity (total, 1-hr. rating)	3,000 kv.-a	2,600 kw
Number of generators (total)	3	4
Rating and type	1,000 kv.-a. 5,500-v 3-phase, 25-cycle	Double current 650 kw. 850 v. d.c. or 600 v. 6-phase, 25-cycle
Type of prime mover	Steam engines	Hydraulic turbines
Number of boilers (total)	12	None
Type	Water-tube	None
Rating (b.h.p.)	8-200, 4-280	None
High Tension Transmission:		
Feeders (circuit miles)—		
On poles (bare wire)	None	70[¶]
Underground (insulated cable)	20	None
Type	3-phase, 25-cycle	3-phase, 25-cycle
Voltage	5,500 a.c.	20,000 a.c.
Substations:		
Number and type	3 rotary[**]	5 rotary
Average distance apart (miles)	4.8	8.75
Capacity (total)	4,500 kw	6,000 kw
Size of rotary converter units	500 kw	600 kw
Size of transformer units	525 kv.-a	600 kv.-a
Rolling Stock:		
Locomotives or motor cars used	Locomotives and motor cars	Motor cars
Number and service	18 locomotives, 7 motor cars	10 passenger, 10 freight
Train weight (average) excluding locomotive (tons, 2,000 lb.)	250	None
Locomotives:		
Class	(A) 0–4–4–0 (B) 0–4–4–0 (C)	None
Total weight (tons)	(A) 55 (B) 60 (C) 90.2	None
Weight on drivers (lb.)	(A) 110,000 (B) 120,000 (C)	None
Number of motors	(A) 4 (B) 4 (C) 2	None
Type of motor	(A) (B) Geared (C) Side-rod	None
Capacity per motor (h.p., 1-hr. rating)	(A) (B) 230 (C) 900	None
Tractive effort of locomotive (lb., 1-hr. rating)	(A) (B) 13,200 (C) 21,000	None
Normal speed of locomotive (rated load on level track) mi. per hr.		None
Motor Cars:		
Weight excluding passengers (tons, 2,000 lb.)	46.2	28.6 passenger 24.2 freight
Seating capacity	32	44
Number of motors	4	4
Capacity per motor (h.p., 1-hr. rating)	175	50
Trailer Cars:		
Weight excluding passengers (tons, 2,000 lb.)		13.2
Seating capacity		44

[*] From Quai d'Orsay to Austerlitz. 100 lb. rail is fitted with two flat rails 25 lb. each as fish plates. Total weight of conducting rail, 150 lb.

[†] 1000–1200 kw. is purchased from a plant at Vitry.

[‡] Also furnishes power to the Perpignan-Ille Line.

[¶] Includes 2.96 miles of cable through tunnel

[**] Each contains storage battery of 1500 amp. hr. capacity.

In 1908, the Bavarian State Railway Administration prepared and submitted to the Landtag a memoir on electric traction for main lines. This memoir referred especially to the Salzburg-Reichenhall-Berchtesgaden line, the Munich-Garmisch line and other minor lines, mostly suburban. The first line to be equipped and operated electrically was the Berchtesgaden-Schellenberg, a local road eight miles long. This installation employs direct current and light motor and trailer car trains. Later a light service local line, operated by the Munich City Railways and known as the Murnau-Oberammergau line, was equipped for alternating current traction.

The Baden State Railway Administration has conducted investigations with reference to this question by electrifying a light service railroad known as the Wiesenthal line. In this installation water power developments have been utilized.

As a result of these trial installations, the three German State Railway Administrations have decided to employ the single-phase alternating current system. The advantages of this form of traction are considered by them to be greater than its disadvantages.

205.38 Zossen Experiments: The section electrified for the purpose of making these experiments comprises a portion of the main line of the Prussian State railroad system between Marienfelde and Zossen near Berlin. The section is about 14 miles in length and is on tangent for practically the entire distance. Grades are light and short, 0.5 per cent being the maximum. The track is of standard construction, with 67-pound rails laid in part on steel ties and in part on wooden ties. In 1901, the line was equipped with overhead electric conductors for three-phase electric operation. A series of elaborate tests with motor cars and with locomotives was undertaken to determine the following important general characteristics of electric traction at high speed:

1. The amount of energy which it is possible to transfer from a stationary conductor to a rapidly moving car at various speeds.
2. The speed and energy curves for electric trains.
3. The maximum speeds which can successfully be operated.
4. The train resistance and power consumption of trains.
5. The braking results at various speeds.

The tests extended over a period of three years. Much time was spent in making the permanent way suitable and safe for operation at high speeds, and changes in the equipment were made from time to time in order to adapt it to the requirements of the various tests. At the end of the first year it was found that defects in the track began to develop at speeds of 80 miles an hour. Pending changes in the permanent way to accommodate the higher speeds, tests were conducted to determine train resistance at speeds up to 75 miles an hour. After the track changes were completed, high speed tests were resumed and speeds as high as 120 miles an hour were attained. Accurate reports on the results of all these elaborate tests were submitted to the German government. They form a valuable and interesting record of work in the early days of electric traction. In general it may be said that the limitations of high speed were found in the stability of the rolling stock and of the track, and in the large current consumption during acceleration. The difficulties of collecting current and operating the electric apparatus at high speeds were not regarded as serious. The distance required in stopping trains running at high speeds was found to influence the limit of safe maximum speeds. Since the completion of the tests, the line in question has not been operated electrically.

205.39 Class A—Trunk Line Railroads—Prussian State Railways—Dessau-Bitterfeld Line: The first important main line electric installation undertaken by the State Railway Administration was on a portion of the state trunk line from Magdeburg to Leipzig, between Dessau and Bitterfeld, a distance of about 16 miles. This electrification was completed in 1911, and careful experimental work has since been conducted to determine the best type of motive power and the most satisfactory details of electric construction in general. After about two years' experimental work, construction has been started on the electrification of the entire line from Leipzig and Halle to Magdeburg. This will include about 95 miles of double track railroad. About 36 locomotives will be required in the operation of the line.

The selection of the Dessau-Bitterfeld section for the initial electrification was due to the fact that it lies in the heart of a great lignite coal district where power can be produced economically. The lignite coal in its natural state is not suitable for use in steam locomotives. It can be successfully burned, however, in stationary plants and affords cheap power for industrial purposes. It was believed that the combination of power supply for industries and for the railroads would tend to reduce the cost of power production.

During the past two years electric operation has been conducted by locomotive trains only. When the line is extended it is probable that motor car trains will be employed to supplement the present service. Both freight and passenger services have been conducted electrically, and many types of electric locomotives, varying from a 66-ton locomotive equipped with a single 800-horse-power motor to a 100-ton locomotive with two 1,250-horse-power motors, have been tested. Experimental work in perfecting details of the rolling equipment and the contact system has also been conducted.

The single-phase alternating current system, which has been adopted as standard for all work of the State Railway Administration, is in use on this line. Current is generated in a steam power plant near Bitterfeld on the River Mulde. Brown coal is used as fuel and is burned on special grates under water-tube boilers. Current is generated as single-phase, 15-cycle, alternating current at 3,000 volts, stepped up to 60,000 volts for transmission to substations by means of one overhead and two underground lines. This high transmission voltage is not required for feeding the short section of railroad in question but was adopted in anticipation of the future extension of the traction system, possibly to Berlin, 80 miles distant. It is the first example of such high voltage in underground cables and is said to have given satisfactory results. The overhead construction is of the catenary type.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION, JAN., 1911

MILEAGE	
Total route miles	16.12
Total track miles	47.70
TRAIN SERVICE	
Passenger	Locomotives
Freight	Locomotives
ELECTRIC TRAIN EQUIPMENT	
Passenger and freight locomotives	7

The accompanying map, fig. 469, shows the location of the electrified lines of the Dessau-Bitterfeld Railway.

TABLE CCXXXIII. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF GERMAN STEAM RAILROAD ELECTRIFICATIONS, CLASS A—TRUNK LINE RAILROADS

Details	Dessau-Bitterfeld Railway
General:	
System of traction	Single-phase alternating current
Conductors:	
Type of working conductor	Overhead trolley
Position	19 ft., 8½ in., maximum, 15 ft., ½ in., minimum, above track
Size and material	Copper 0.39 in. equiv. diam.
Type of collector	Bow pantograph
Transmission voltage	60,000, single-phase
Contact voltage	10,000, single-phase
Power Generation:	
Owner of plant	Railway Company
Number of plants and type	1 steam-electric
Location	Muldenstein
Plant capacity (total, 1-hr. rating)	3,000 kv-a.
Number of generators (total)	1
Rating and type	3,000 kv-a. 3,000-v. single-phase, 15-cycle
Type of prime mover	Steam turbine
Number of boilers (total)	4
Type	Water-tube
Rating (b. h. p.)	
High Tension Transmission:	
Feeders (circuit miles)	
On poles (bare wire)	5.46
Underground (insulated cable)	10.92
Type	Single-phase, 15-cycle
Voltage	60,000 a.c.
Substations:	
Number and type	1 static
Average distance apart	None
Capacity (total)	3,600 kv-a.
Size of rotary converter units	None
Size of transformer units	1,800 kv-a.
Rolling Stock:	
Locomotives or motor cars used	Locomotives
Number and service	7 passenger and freight
Train weight (average) excluding locomotive (tons, 2,000 lb.)	350 passenger, 1,400 freight
Locomotives:	
Class	(A) 4-4-2 (B) 0-8-0 (C) 2-8-2 (D) 2-6-2
Total weight (tons)	(A) 77-79.2 (B) 66 (C) 100.1-101.2 (D) 77-79.2
Weight on drivers (lb.)	(A) 66,000 (B) 132,000 (C) 132,000 (D) 89,000
Number of motors	(A) 1 (B) 1 (C) 2 (D) 1
Type of motor	(A) (B) (C) (D) } side-rod
Capacity per motor (h.p., 1-hr. rating)	(A) 1,000-1,100 (B) 800 (C) 950-1,250 (D) 1,800-1,100
Tractive effort of locomotive (lb., 1-hr. rating)	(A) 14,300 (B) (C) (D)
Normal speed of locomotive (rated load, on level track), mi. per hr.	(A) 68.5 (B) 15.5 (C) 43.5 (D) 56.0
Motor Cars:	
Weight excluding passengers (tons, 2,000 lb.)	None
Seating capacity	None
Number of motors	None
Capacity per motor (h.p., 1-hr. rating)	None
Trailer Cars:	
Weight excluding passengers (tons, 2,000 lb.)	None
Seating capacity	None

205.40 Class A—Trunk Line Railroads—Technical Characteristics: Table CCXXXIII presents a summary of the general and technical characteristics of electrifications of German steam railroads included in Class A—Trunk Line Railroads.

205.41 Class B—Secondary Railroads—Mittenwald Railway: This is a standard gage railroad built to be operated by electric traction. While in many particulars it partakes of the nature of heavy interurban electric service as operated in America, it is typical of many steam railroads of Europe in that it handles a large passenger traffic through a country which requires heavy motive power for light trains. The road is located partly in Austria and partly in Germany and is constructed in four sections grouped together under the name of the Mittenwald Railway. It extends from Innsbruck to Reutte, a distance of 63 miles, and crosses the German boundary into Bavaria at Scharnitz and again at Griesen. The total length of line in Bavaria is 21 miles.

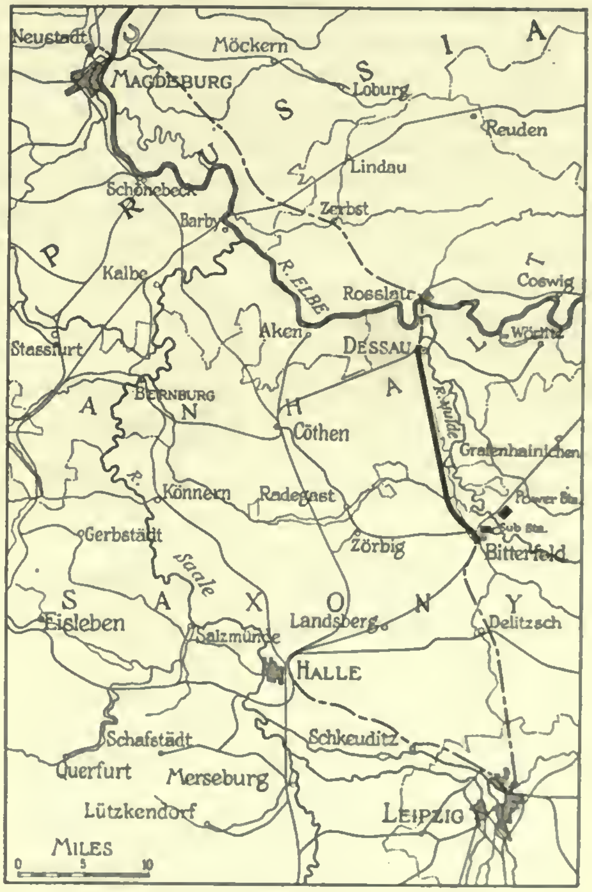

FIG. 469. ELECTRIFIED LINES OF THE DESSAU-BITTERFELD RAILWAY

The region traversed by this railroad, Bavarian and Austrian Tyrol, is mountainous and presents many difficulties in railroad location. The Austrian section of the line out of Innsbruck was built with grades as heavy as 3.64 per cent and required the construction of 18 tunnels.

As the building of the railroad on the location adopted was predicated upon its operation by electricity, heavier grades were allowed than would be practicable with steam operation. The adoption of the 3.64 per cent ruling grade effected a large saving in construction costs and reduced the length of the line by about 2.5 miles. The estimated saving in construction costs exceeded the total cost of equipment for electric operation. Another determining factor in the adoption of electric traction was the high cost of coal and the availability of hydro-electric power.

Eight through passenger trains and two freight trains are operated daily from Reutte to Innsbruck, and special provision is made for extra trains to accommodate Sunday and holiday traffic. Electric locomotives handle trailing loads averaging 135 tons on the maximum grade of 3.64 per cent at a speed of about 11.5 miles an hour. These are arranged for operation on the multiple-unit control system, thereby permitting two or more locomotives to be used on the heavier trains.

The single-phase alternating current system with an overhead trolley is used. Power is generated by 3,000-volt, 15-cycle generators at the railroad's hydro-electric plant, situated about four miles south of Innsbruck. The current is stepped up to 50,000 volts and transmitted to transformer substations at Reith and Scharnitz, where it is transformed and fed to the overhead trolleys at 15,000 volts. Power is also purchased from the municipal plant at Innsbruck. Eventually the entire German section of the road from Scharnitz to Griesen will be fed from the new hydro-electric development at Walchen See.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION, OCT., 1912

MILEAGE	
Total route miles	62.7
Total track miles	66.1
TRAIN SERVICE	
Passenger	Locomotives
Freight	Locomotives
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)	
Passenger	8
Freight	2
ELECTRIC TRAIN EQUIPMENT	
Freight and passenger locomotives	9

The accompanying map, fig. 470, shows the location of the electrified lines of the Mittenwald Railway.

205.42 Class B—Secondary Railroads—Wiesenthal Railway: This railroad, which was formerly operated by steam, was converted to electric operation in 1912. It is owned by the Grand Duchy of Baden and extends from Basel to Schopfheim, with a branch to Säckingen and one to Zell, and has a total of about 31 miles of route and 52 miles of single track. Its average grade is light, and its maximum is less than one per cent. One tunnel, 2.5 miles long, is located on the line.

The electrification is a result of the program adopted by the Baden State Railway for the purpose of utilizing the water power of the Black

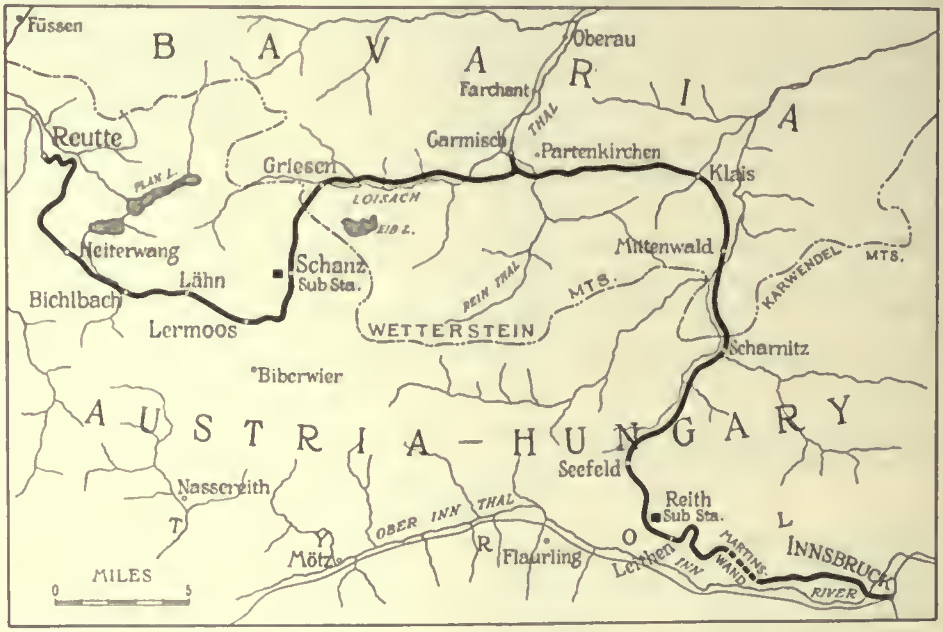

FIG. 470. ELECTRIFIED LINES OF THE MITTENWALD RAILWAY

Forest district. It is in the nature of an experimental electrification undertaken to test the economic and technical features of this form of traction.

Both freight and passenger trains are handled by electric locomotives, 13 of which are in use. Freight trains have an average weight of about 500 tons and passenger trains a maximum of 250 tons. Standard steam railroad passenger coaches are used. About 60 passenger and 22 freight trains are operated daily.

Single-phase alternating current at 10,000 volts and 15 cycles is used with an overhead trolley. Power is supplied by a hydro-electric station near Basel as polyphase current at 6,800 volts and 50 cycles. It is transmitted to a rotary converter station at Basel, where it is converted and transformed into single-phase current of proper voltage and frequency. A complicated arrangement of storage batteries and rotary converters is employed to reduce the peak loads on the power plant.

The accompanying map, fig. 471, shows the location of the electrified lines of the Wiesenthal Railway.

205.43 Class B—Secondary Railroads—Technical Characteristics: Table CCXXXIV presents a summary of the general and technical characteristics of electrifications of German steam railroads included in Class B—Secondary Railroads.

205.44 German Electrification Projects under Construction or in Contemplation: The important electric traction projects in Germany now (1914) in process of construction or definitely decided upon include the following:

1. Heavy trunk line electric operation on the Magdeburg-Leipzig-Halle line of the Prussian State Railways.
2. Terminal and city electric traction operation on the Berlin Stadtbahn ("City Railway") of the Prussian State Railways.
3. Trunk line electrification of the Lauban-Königszelt line of the Prussian State Railways.
4. Heavy electric traction on secondary railroads of the Salzburg-Reichenhall-Berchtesgaden line of the Bavarian State Railways.

The Magdeburg-Leipzig-Halle line is an extension of that on the portion of the line between Dessau and Bitterfeld. Construction for electric operation is now (1914) in progress and when completed will include about 95 miles of double track. The single-phase alternating current traction system has been adopted and it is contemplated that the operation of heavy main line freight and passenger service will be conducted by electric locomotives. No detailed description of the work is as yet available. It is understood, however, that the standards of line construction and locomotive design developed on the Dessau-Bitterfeld line are to be adopted and that power will be taken from the power plant near Bitterfeld, which has been designed as a central plant for all the German State Railway electrifications including that in Berlin. When completed, this electrification will constitute the first important long main line electric traction installation in Germany.

The proposed electrification of the Berlin Stadtbahn, or "City Railway," of the Prussian State Railway System is of interest because this road is used in part as a "distributed terminal" for many of the through lines of the Prussian Government railroads, and because the initial electrification is to be undertaken with a view to extending it later to include through traffic. The Berlin Stadtbahn is elevated on viaducts and embankments through the central portion of the city, and also forms a belt line around the city. The east and west line bisects the belt railroad and forms the part of the system which is used as the "distributed terminal" for long distance main line traffic. Both the central line and the belt serve a very heavy local city passenger business. and operate a frequent service similar to that on American elevated railways and subways. In 1909 the City Railway carried 157,000,000 passengers, and the traffic is increasing rapidly. The

FIG. 471. ELECTRIFIED LINES OF THE WIESENTHAL RAILWAY

TABLE CCXXXIV. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF GERMAN STEAM RAILROAD ELECTRIFICATIONS, CLASS B—SECONDARY RAILROADS

Details	Mittenwald Railway	Wiesenthal Railway
General:		
System of traction	Single-phase alternating current	Single-phase alternating current
Conductors:		
Type of working conductor	Overhead trolley	Overhead trolley
Position		
Size and material	Two copper wires 0.27 in. equiv. diameter	Copper 0.44 in. equiv. diameter
Type of collector	Bow pantograph with double contacts	Sliding bow trolley
Transmission voltage	50,000, single-phase	6,800, 3-phase
Contact voltage	15,000, single-phase	10,000, single-phase
Power Generation:		
Owner of plant	Railway Company	Purchased from the Rheinfelden Power Company
Number of plants and type	1 hydro-electric*	1 hydro-electric
Location	Near Innsbruck	Wyhlen
Plant capacity (total, 1-hr. rating)	6,000 kv-a	2,500 kw
Number of generators (total)	2	None
Rating and type	3,000 kv-a. 3,000-volt, single-phase 15-cycle	A.C. at 6,800 volts
Type of prime mover	Hydraulic turbines	None
Number of boilers (total)	None	None
Type	None	None
Rating (b.h.p.)	None	None
High Tension Transmission:		
Feeders (circuit miles)—		
On poles (bare wire)	50.5	5.5
Underground (insulated cable)	None	None
Type	Single-phase, 15-cycle	3-phase, 50-cycle
Voltage	50,000 a c	6,800 a.c
Substations:		
Number and type	2 static	1 motor-generator
Average distance apart (miles)	36	None
Capacity (total)	3,200 kv-a.	4,200 kv-a.
Size of rotary converter units	None	2 – 2,100 kv-a. (motor generators)
Size of transformer units	400 kv-a., 1,000 kv-a.	None
Rolling Stock:		
Locomotives or motor cars used	Locomotives	Locomotives
Number and service	9 locomotives, freight and passenger	13 locomotives, freight and passenger
Train weight (average) excluding locomotive (tons, 2,000 lb.)	135†	250 passenger, 500 freight
Locomotives:		
Class	2-6-0	2-6-2
Total weight (tons, 2,000 lb.)	53	72.6
Weight on drivers (lb.)		92,400
Number of motors	1	2
Type of motor	Side-rod drive	Side-rod drive
Capacity per motor (h.p., 1-hr. rating)	800	475
Tractive effort of locomotive, (lb., 1-hr. rating)		8,820
Normal speed of locomotive (rated load on level track) mi. per hr.	18.6	37.9
Motor Cars:		
Weight excluding passengers (tons, 2,000 lb.)	None	None
Seating capacity	None	None
Number of motors	None	None
Capacity per motor (h.p., 1-hr. rating)	None	None
Trailer Cars:		
Weight excluding passengers (tons, 2,000 lb.)	None	None
Seating capacity	None	None

* Power is also purchased from the Sill hydro-electric plant at Innsbruck.
† On 3.64 per cent grade.

central line of four tracks serves the important through stations, such as Charlottenburg, Zoölogical Gardens, Friedrichsstrasse and the Schlesischer Station. Congestion of traffic on this portion of the system has become acute. Under steam operation a service of only 24 trains an hour in each direction has been possible, whereas a service of 40 trains an hour will soon be needed to meet the requirements. Electrification of the line, which will permit the running of longer trains at higher average speeds, seemed the only practical remedy. In order to utilize the present equipment, which represents a heavy investment, it is the intention to make up the trains with an electric locomotive at each end, and it is estimated that this arrangement will not only be less expensive in first cost than the multiple-unit car trains but that the weight of the trains will be less and the maintenance cost lower. During the hours of heaviest traffic trains will consist of 13 six-wheel coaches and two locomotives, and during periods of lighter traffic they will consist of six or seven cars and one locomotive. By fitting the rear passenger coach of the lighter train with an electric controller, it will be possible to drive the train from either end. No decision has as yet been reached in regard to the system of traction to be adopted. Electric power will be supplied from two stations, one located at Bitterfeld, about 80 miles distant, where lignite coal is available, and the other in Berlin. The latter station will be used to provide for the peak loads. Power is to be transmitted at 60,000 volts from the Bitterfeld station by underground cables. It is intended that each power plant shall eventually have a capacity of 100,000 kilovolt-amperes. It is stated that electric operation of the Stadtbahn will require 557 electric locomotives and 690 additional passenger coaches.

The Lauban-Königszelt line, and certain of its branches near Breslau in Silesia, will be electrified in connection with the program of the administration of the Prussian State Railways for trunk line electrification. This important electrification will comprise about 80 miles of main line and 85 miles of branch lines. The electrification was decided upon because, in contrast to the Magdeburg-Halle line, it presented conditions of operation on heavy gradients and sharp curves, which afforded an opportunity for the study of the behavior of electric apparatus under exceptionally difficult physical conditions. The road crosses the densely populated industrial section of lower Silesia and serves a number of summer and winter resorts in the Riesengebirge.

The volume of traffic is exceptionally uniform throughout the year, in consequence of the fact that a large part of the freight business consists of coal traffic from the Waldenburg fields. The tourist business is heavy and uniform. It is contemplated that all trains will be operated by electric locomotives of a type suitable to the tonnage and speed in the different services. Power will be generated in a steam plant near Neurode. Coal from the Waldenburg district, having a heating value of 6,500 British thermal units and costing about $1.60 per ton, will be used. The traction system will employ single-phase, 16⅔-cycle, alternating current at 15,000 volts. Current generated at the power plant will be stepped up to 60,000 or 80,000 volts and transmitted to substations where it will be transformed to the working voltage. The power plant for this operation is now being constructed by private capital. The railroad administration has contracted to take a minimum of 40,000,000 kilowatt-hours a year at a price of about 0.7 cent per kilowatt-hour at the high tension bus-bar. The contract for power will cover a period of 30 years, at the end of which time the government may take over the plant at an appraised value. As in the case of other state railroad electrification work, the large electric companies of the country have combined to furnish the equipment, each company supplying the type of apparatus it considers best adapted to the requirements.

The electrification of the Salzburg-Reichenhall-Berchtesgaden line, a secondary line of the Bavarian State Railway, is now in progress. This road extends from Berchtesgaden, in the southeastern part of Upper Bavaria, to the Austrian city of Salzburg, a total route distance of 25 miles, 20 per cent of which is in Austrian territory. Although running through the heart of the Bavarian Alps and having long grades as high as 4 per cent, the line is of normal gage. There is at present a high tension, direct current, light local railroad handling passenger traffic and operating between Salzburg and Berchtesgaden over a more direct route than that of the state railroad. The railroad now being equipped for electric operation will use single-phase, 15-cycle current at 10,000 or 15,000 volts. Power is to be generated in a hydro-electric station at Reichenhall. Both freight and passenger traffic are to be handled electrically. For this purpose twelve electric locomotives and two motor cars will be provided. The traffic will require the operation of about 36 passenger and four freight trains daily.

SWISS RAILROAD ELECTRIFICATIONS

205.45 Character of Electrifications in Switzerland: Railroad electrification in Switzerland is of particular interest owing to the variety of difficult conditions attendant upon operation in a mountainous country. There are few Swiss installations, however, which are comparable with American trunk line railroads as regards operation under heavy traffic conditions. All electrifications in Switzerland have been based upon the utilization of water power. The cost of coal is high and that of hydro-electric power is low. In some cases the difficulty arising from smoke in the long tunnels forms another important reason for the adoption of electric traction, and in other cases a contributing factor has been the ability to increase the capacity of a crowded line by means of the higher speed and greater tractive effort which is secured by the use of electric locomotives.

Of the existing Swiss electrifications, those of the Simplon and Loetschberg tunnel lines are the only ones which approach American trunk railroad operation in importance. Of projected work, the electrification of the St. Gotthard tunnel line, now (1914) in progress, is the most extensive. Of secondary line electrifications, both for fairly heavy traffic and for light special traffic, there are a number of examples, all of which present points of interest to the engineer rather than conditions which bear upon the electrification problem of Chicago.

205.46 Class A—Trunk Line Railroads—Simplon Tunnel Railway: The Simplon tunnel furnishes one of the two important through connecting links between Italy, Switzerland and the north of Europe. Trains by this route operate from points on Lake Geneva via Martigny and the Rhone Valley to Domodossola, Italy, and thence to Arona on Lake Maggiore and the south. The construction of this tunnel, which is the longest in the world (12.25 miles), was started in 1898 and the line was opened for traffic in June, 1906. The summit of the tunnel is very low, being only 2,313 feet above sea level, and the tunnel gradients are comparatively easy, with a maximum of 0.7 per cent. High temperatures were encountered during construction, necessitating special provision for ventilation, both for construction work and for subsequent operation. The initial plan provided for two single track tunnels to be located about 56 feet apart, inter-connected by cross passages to provide for ventilation. Only one of these tunnels has been completed for train operation. The other tunnel was built as a construction heading and is now being enlarged and equipped for a second track.

Because of the length of the tunnel and the high natural temperature of the rock formations through which it passes, it was necessary to adopt some system of traction other than steam locomotive operation. In 1898, soon after the work had been started, proposals were made to the Jura-Simplon Railway Company to consider plans for operating the line with electricity, but as the art of heavy electric traction was then in its infancy, the proposals were rejected. Subsequent attempts to interest the management in electric operation met with a similar fate. In 1905, when the tunnel was nearing completion, the Brown-Boveri Company, of Baden, Switzerland, proposed to electrify the road at its own expense and to operate the trains through the tunnel with three-phase alternating current locomotives at a fixed charge per train-mile. The railroad company had the option of taking over the electric installation at the end of a year or of compelling the contractors to remove it at their own expense. This offer was accepted December 19, 1905, and by June 1, 1906, regular electric operation was inaugurated and has since been successfully conducted.

Electric operation is confined to the tunnel and its approaches. All trains, both freight and passenger, are hauled through the tunnel by electric locomotives, of which two types are used, one for freight trains and one for passenger trains. Freight trains are operated at about 21 miles an hour and passenger trains at 42 miles an hour.

Three-phase alternating current is employed with two overhead contact wires above each track and with three-phase motors on the locomotives. Power is generated as three-phase, 3,300-volt, 16-cycle, alternating current in two hydro-electric power stations, one located near each portal of the tunnel.

During the enlargement of the second tunnel, which began in January, 1913, the plant at Iselle was used for construction purposes only, and power for operating the railroad was obtained from the new hydro-electric plant at Varzo, owned by a private Italian company. Plans have been made to obtain power permanently from this station when the new tunnel line is opened, and to abandon the plant at Iselle.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION, JUNE, 1906	
MILEAGE	
Total route miles	13.7
Total track miles	17.9
TRAIN SERVICE	
Passenger	Locomotives
Freight	Locomotives
AVERAGE NUMBER OF CARS PER TRAIN	
Passenger	10–15
Freight	30–50
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)	
Passenger	17
Passenger and goods	4
Freight	5
ELECTRIC TRAIN EQUIPMENT	
Freight and passenger locomotives	4
TRAIN-MILES PER ANNUM (1913)	
Passenger	88,578
Passenger and goods	9,439
Freight	107,880
TRACTION POWER REQUIREMENTS (1913)	
Maximum load, kw.	1,492
Total per annum, kw-hr.	1,650,000

The accompanying map, fig. 472, shows the location of the electrified line of the Simplon Tunnel Railway.

205.47 Class A — Trunk Line Railroads — Loetschberg Railway: This new railroad is practically a continuation of the Simplon Tunnel line and forms the shortest route through France from Calais or Boulogne via Switzerland to Milan and the central artery of the Italian railroad system. It affords also a short route from Italy to the important Swiss cities and to points in Germany. The new railroad construction extends from Frutigen to Brieg, near the entrance of the Simplon tunnel, a distance of 37.5 miles, but its main terminus is at Spiez, 8.3 miles north of Frutigen, on the lake of Thun. At the town of Thun connections are made for through service over the Continental trunk lines. The Spiez-Frutigen section, originally a steam road, was electrified for experimental purposes in 1910. The new road to Brieg was electrified upon its completion and was placed in operation in July, 1913. The entire road abounds in examples of bold engineering construction. From Spiez the railroad follows the valley of the Kander to Kandersteg, the entrance to the great tunnel from which the road takes its name. The Loetschberg tunnel is 9.1 miles long, with 15 per cent of its length on curves. Its summit is 4,077 feet above sea level. The gradients in the tunnel are 0.7 per cent from the north portal to a point near the center, where there is a short stretch of level track, and 0.4 per cent descending to the south portal. The line as a whole has 33 minor tunnels, the combined length of which is equivalent to 22.5 per cent of the total length of the road. Including the mileage of the main tunnel nearly 43 per cent of the line is in tunnels. The Loetschberg line

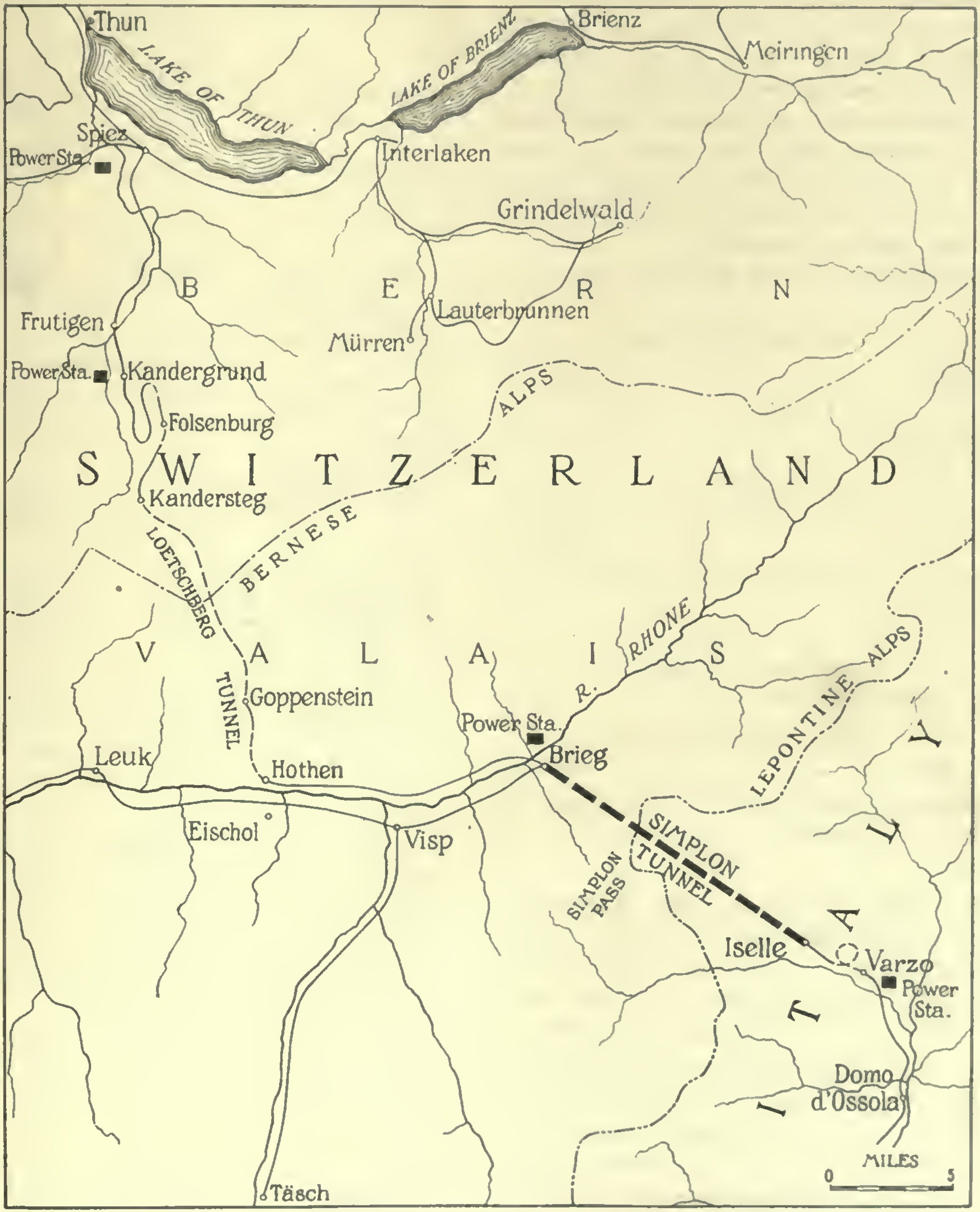

FIG. 472. ELECTRIFIED LINE OF THE SIMPLON TUNNEL RAILWAY

has been constructed in such manner as to permit of its being double tracked throughout. At present only 10.5 miles, including the main tunnel, are of double track construction. Electric traction was adopted to avoid the smoke nuisance in the long tunnel and to utilize the cheap hydro-electric power available as a substitute for steam power from coal which, in this district, costs from $7.00 to $8.00 a ton.

The single-phase alternating current system of traction is employed on the entire line. Power is purchased from the Bern Power Company, whose hydro-electric generating stations are located at Kandergrund and Spiez. Single-phase current is delivered at 15,000 volts, 15 cycles. Fourteen locomotives of the 2–10–2 type, weighing from 100 to 108 tons each and having 85 tons on the drivers, are used.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION	
Spiez to Frutigen	1910
Frutigen to Brieg	July, 1913
MILEAGE	
Total route miles	45.8
Total track miles	60.0
TRAIN SERVICE	
Passenger, through	Locomotives
Passenger, local	Motor cars
Freight	Locomotives
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)	
Passenger, through	10
Passenger, local	6
Freight	8
ELECTRIC TRAIN EQUIPMENT	
Passenger and freight locomotives	14
Motor cars	3
TRACTION POWER REQUIREMENTS (1913)	
Total per annum, kw-hr.	10,000,000

The accompanying map, fig. 473, shows the location of the electrified lines of the Loetschberg Railway.

205.48 Class A—Trunk Line Railroads—Technical Characteristics: Table CCXXXV presents a summary of general and technical characteristics of electrifications of Swiss steam railroads in Class A—Trunk Line Railroads.

205.49 Class C—Light Service Railroads—Burgdorf-Thun Railway: The Burgdorf-Thun Railway was the first important standard gage electric railroad constructed in Switzerland. It is a single track connecting line, about 25 miles long, with one terminal station on the main line from Zürich via Bern to Geneva, and another on the line from Bern to Thun and Interlaken. It also crosses the line between Bern and Lucerne.

TABLE CCXXXV. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF SWISS STEAM RAILROAD ELECTRIFICATIONS. CLASS A—TRUNK LINE RAILROADS

Details	Simplon Railway	Loetschberg Railway
General:		
System of traction	3-phase alternating current	Single-phase alternating current
Conductors:		
Type of working conductor	2 double overhead trolleys	Overhead trolley
Position	17 ft., 5 in., maximum 15 ft., 9 in., minimum above tracks	23 ft., 0 in., maximum 15 ft., 8 in., minimum above tracks
Size and material	Copper 0 31 in. equiv. diam.	Copper 0 44 in. equiv. diam.
Type of collector	Two part sliding bow trolley	Sliding bow trolley
Transmission voltage	None	None
Contact voltage	3,300, 3-phase	15,000 single-phase
Power Generation:		
Owner of plant	Railway Company	Purchased from Bern Power Company
Number of plants and type	1 hydro-electric	2 hydro-electric
Location	Brieg[*]	Kandergrund and Spies
Plant capacity (total, 1-hr. rating)	900 kw.	
Number of generators (total)	1	None
Rating and type	900 kv-a., 3,300-v., 16-cycle, 3-phase	A. C. at 15,000 volts
Type of prime mover	Hydraulic turbines	None
Number of boilers (total)	None	None
Type	None	None
Rating (b.h.p.)	None	None
High Tension Transmission:		
Feeders (circuit miles)—		
On poles (bare wire)	None	None
Underground (insulated cable)	None	None
Type	None	None
Voltage	None	None
Substations:		
Number and type	None	None
Average distance apart (miles)	None	None
Capacity (total)	None	None
Size of rotary converter units	None	None
Size of transformer units	None	None
Rolling Stock:		
Locomotives or motor cars used	Locomotives	Locomotives and motor cars
Number and service	4 locomotives, freight and passenger	14 locomotives and 3 motor cars
Train weight (average) excluding locomotive (tons, 2,000 lb.)	385 passenger, 726 freight	330
Locomotives:		
Class	(A) 2–6–2 (B) 0–8–0	2–10–2
Total weight (tons)	(A) 68 (B) 75	117.7
Weight on drivers (lb.)	(A) 96,800 (B) 150,000	176,000
Number of motors	2	2
Type of motor	Side-rod drive	Geared side-rod drive
Capacity per motor (h.p., 1-hr. rating)	(A) 400–550. (B) 550–850	1,250
Tractive effort of locomotive (lb., 1-hr. rating)	(A) 12,760– 8,800 (B) 25,300–14,080	29,700
Normal speed of locomotive (rated load on level track) mi. per hr.)	(A) 21.8–43.6 (B) 16.2–43.6	31
Motor Cars:		
Weight excluding passengers (tons, 2,000 lb.)	None	60.5
Seating capacity	None	64
Number of motors	None	2
Capacity per motor (h.p., 1-hr. rating)	None	225
Trailer Cars:		
Weight excluding passengers (tons, 2,000 lb.)	None	None
Seating capacity	None	None

[*] Power is also purchased from the hydro-electric station at Varzo.

Leaving Burgdorf, 1,758 feet above sea level, the line ascends for nearly 13.5 miles with an average grade of 1.15 per cent and a maximum of 2.5 per cent, and attains an altitude of 2,526 feet near Biglen. From this point the line descends to Thun, 1,842 feet above sea level, with an average grade of 1.05 per cent.

The original plan provided for a steam road between Burgdorf and Thun. The road was first projected about 1880 but, because of the heavy grades and probable high cost of operation, construction was deferred. When electric operation became sufficiently developed to be applicable to heavy traction, one of the prominent manufacturing companies offered to equip the line and guarantee its successful operation. Electrification, therefore, was undertaken primarily for the purpose of making practicable the construction

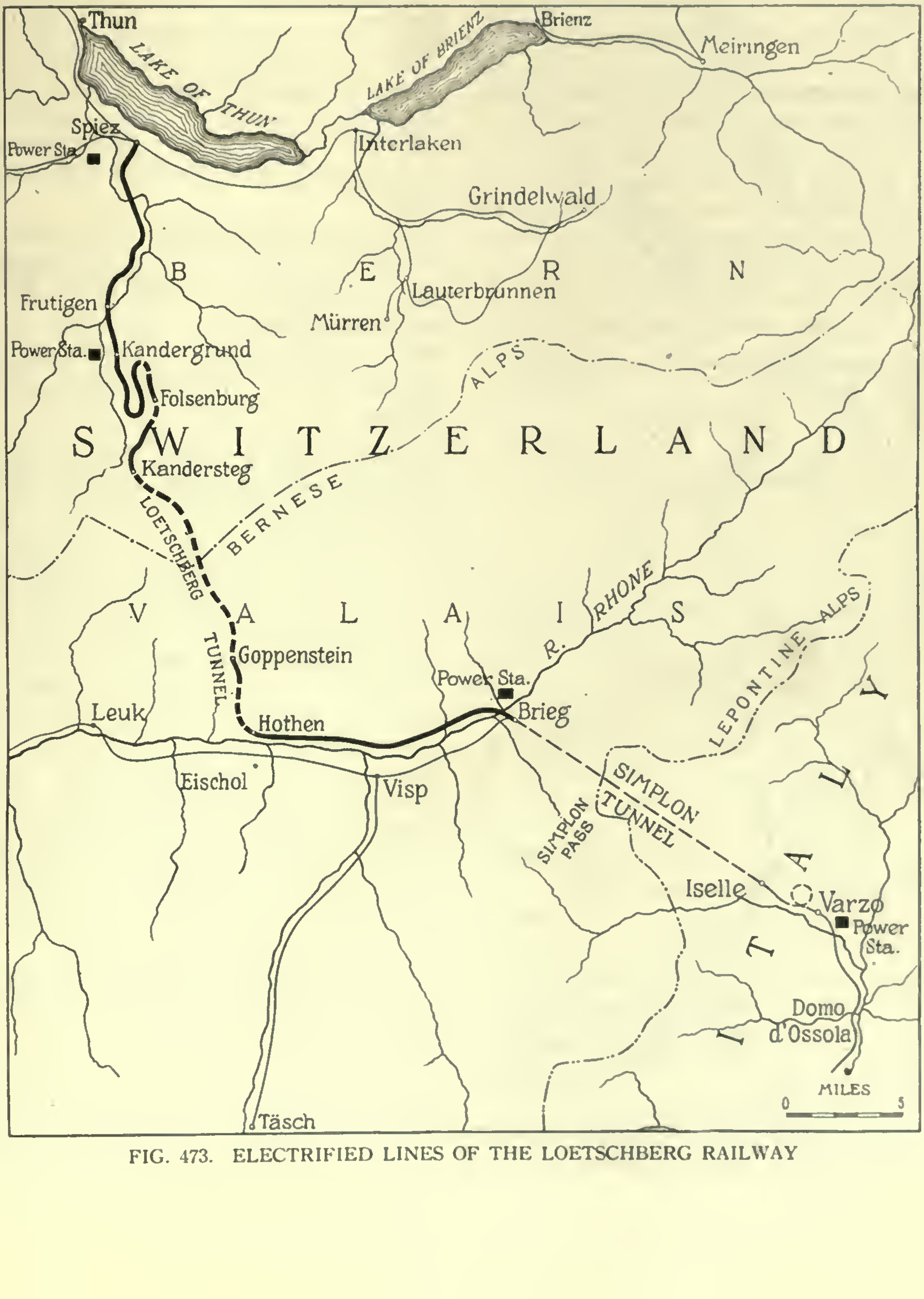

FIG. 473. ELECTRIFIED LINES OF THE LOETSCHBERG RAILWAY

and operation of a railroad with grades heavier than those allowable under steam operation.

This road, as well as the steam line from Solothurn to Langnau, is operated by the Emmenthalbahn Company, and the first 4.5 miles out of Burgdorf are used by both lines. The passenger traffic is light and is handled by motor cars or locomotives with one or two trailer coaches. Freight trains are handled by electric locomotives. About 32 passenger and 9 freight trains are operated daily.

The only electric systems available for traction purposes at the time of construction were the three-phase and direct current. The hydro-electric developments in the vicinity were supplying three-phase current, and this system was therefore adopted under an arrangement which permits the transmission of current direct to the contact lines and its use in three-phase motors. Power is purchased from the Bern Power Company's Kander power station near Spiez and delivered at 16,000 volts, three-phase to transformer stations about 1.8 miles apart. At these stations the current is transformed to 750 volts.

FIG. 474. ELECTRIFIED LINES OF THE BURGDORF-THUN RAILWAY

General statistics of this electrification are:

DATE OF INITIAL ELECTRIC OPERATION, JULY, 1899	
MILEAGE	
Total route miles	24.92
Total track miles	31.00
TRAIN SERVICE	
Passenger	Motor cars and locomotives
Freight	Locomotives
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)	
Passenger	32
Freight	9
ELECTRIC TRAIN EQUIPMENT	
Passenger and freight locomotives	3
Motor cars	6
Trailer cars	14
CAR-MILES PER ANNUM (1913)	
Passenger	10,461
Freight	13,013
TRAIN-MILES PER ANNUM (1913)	
Passenger	6,254
TRACTION POWER REQUIREMENTS (1913)	
Maximum load, kw.	1,911
Total per annum, kw-hr.	2,500,000

The accompanying map, fig. 474, shows the location of the electrified lines of the Burgdorf-Thun Railway.

205.50 Class C—Light Service Railroads—Fribourg-Morat-Anet Railway: This electrification is of interest only as being the first normal gage steam railroad in Switzerland to be electrified. Originally the road extended from Fribourg to Morat, and was operated by steam. It was electrified in 1902. In 1903 an extension of 6 miles from Morat to Anet was built for electric operation. The line is the only normal gage road in Switzerland which has been electrified on the 840-volt direct current third rail system. Traffic is conducted by motor car trains. While the technical results have been satisfactory, electric operation, owing to the small amount of business handled, has not been a success financially.

The accompanying map, fig. 475, shows the location of the electrified lines of the Fribourg-Morat-Anet Railway.

205.51 Class C—Light Service Railroads—Seebach-Wettingen Railway: This was an experimental electric traction installation on a Swiss standard gage railroad, undertaken, as were the Zossen experiments in Germany, to determine the possibilities of single-phase electric traction. The line, which is about 12 miles in length, was equipped in 1907. It was operated electrically for about 18 months, after which period the electric installation was removed.

205.51 Class C—Light Service Railroads—Seethal Railway: This is a single-phase electric railroad of the suburban class, extending from Lucerne to Wildegg, a distance of about 34 miles. Electric operation was inaugurated in 1910. The road constitutes the first permanent single-phase standard gage electrification in Switzerland. The traffic consists largely of passenger trains, of which about 20 run daily in both directions. Four freight trains a day are also operated. All trains are handled by motor cars.

The accompanying map, fig. 476, shows the location of the electrified lines of the Seethal Railway.

205.53 Class C—Light Service Railroads—Bernina Railway: This is a passenger railroad in the Engadine, with a large tourist traffic. It extends from St. Moritz, 5,423 feet above sea level, through the famous Bernina Pass at an elevation of 6,880 feet, to Tirano, Italy, at an elevation of 1,300 feet. The line has a total length of 37.7 route miles. Very heavy grades with a maximum of 7 per cent exist on both sides of the Bernina Pass. The average grade over the line is 4.77 per cent. These are the heaviest grades to be found on Swiss adhesive railroads. At St. Moritz the road connects with the newly electrified Rhätische line to Schuls, and at Tirano with the terminal of the Valtellina Railway. The Bernina Railway is of one meter gage and is typical of Swiss narrow gage lines. It has a heavy passenger traffic handled by motor car trains. The electric system employs direct current at 750 volts, with an overhead trolley wire. Power is generated in a hydro-electric plant as high tension, three-phase current, transmitted and converted to direct current in the usual manner. Trains vary in weight from 45 to 150 tons, and speeds vary according to the grade from 11 to 28 miles an hour. Electric operation was begun in July, 1908, and the line subsequently equipped in sections until its completion in July, 1910.

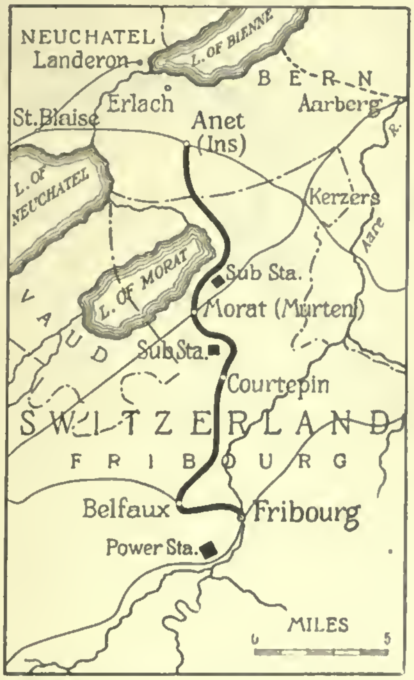

FIG. 475 ELECTRIFIED LINES OF THE FRIBOURG-MORAT-ANET RAILWAY

FIG. 476. ELECTRIFIED LINES OF THE SEETHAL RAILWAY

The accompanying map, fig. 477, shows the location of the electrified lines of the Bernina Railway.

205.54 Class C—Light Service Railroads—Rhätische Railway: This is an electrification of

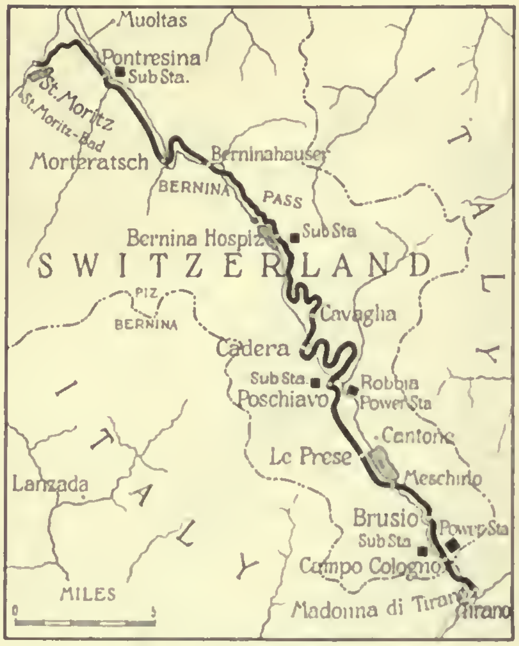

FIG. 477. ELECTRIFIED LINES OF THE BERNINA RAILWAY

that portion of the Rhätische Railway extending from St. Moritz to Schuls, and of a branch from Samaden to Pontresina. The gage is one meter and the maximum grade is 2.5 per cent. The railroad is an example of a light service line possessing a traffic principally of excursion business conducted by locomotive trains. The system of traction employs single-phase alternating current at 10,000 volts with overhead trolley wire. The maximum weight of trains is 200 tons and the average speed about 17 miles an hour, with a maximum speed of 27 miles an hour. The road was placed in operation in 1913.

The accompanying map, fig. 478. shows the location of the electrified lines of the Rhätische Railway.

205.55 Class C — Light Service Railroads — Technical Characteristics: Table CCXXXVI presents a summary of the general and technical characteristics of electrifications of Swiss steam railroads included in Class C—Light Service Railroads.

205.56 Swiss Electrification Projects under Construction or in Contemplation: The electrification of the St. Gotthard Railway, now (1914) in progress, marks a most important electrical undertaking of the Swiss Federal Railways. The plan contemplates electrification of the entire railroad from Lucerne to Chiasso, on the Italian frontier, a distance of approximately 140 miles. Initially, however, only the section between Erstfeld and Bellinzona will be equipped, a distance of about 68 miles including the northerly grade section, the St. Gotthard tunnel and the southerly heavy grade section. The St. Gotthard Railway is the first of the two through routes which have been established from Italy to the north of Europe via Basel to Calais, on the English Channel. Of the 68 miles included in the initial electrification, about 19 miles, or 28 per cent, are in tunnel. The main tunnel at the summit of the pass is 9.25 miles long and 3,800 feet above sea level. Construction on the tunnel was begun in 1872 and completed in 1880, a considerable period of time before the approaches connecting its north end with Lake Lucerne and its south end with the Italian lake district were completed. These approaches involved difficult engineering problems, and in order to keep the grades within the limit of 2.6 per cent it was necessary to resort to line lengthening

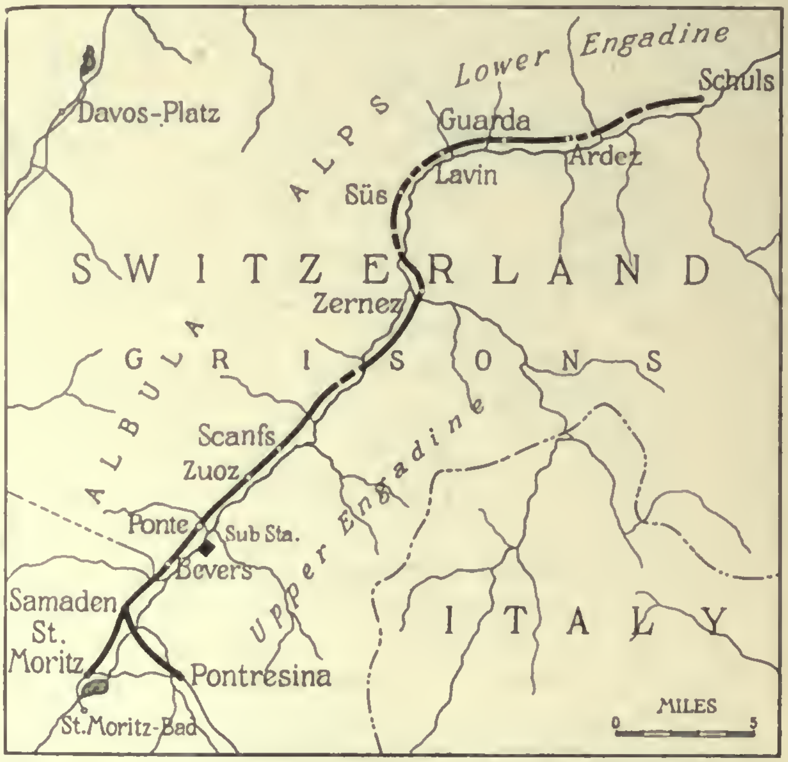

FIG. 478. ELECTRIFIED LINES OF THE RHÄTISCHE RAILWAY

TABLE CCXXXVI. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF SWISS STEAM RAILROAD ELECTRIFICATIONS, CLASS C — LIGHT SERVICE RAILROADS

Details 1	Burgdorf-Thun Railway 2	Rhätische Railway 3	Fribourg-Morat-Anet Railway 4	Bernina Railway 5
General:				
System of traction	3-phase alternating current	Single-phase alternating current	Low tension direct current	Low tension direct current.
Conductors:				
Type of working conductor	Overhead trolley	Overhead trolley	Third rail	Overhead trolley
Position	17 ft. 0 in. above track	19 ft. 8 in. above track	Over running	13 ft. 1½ in., min., 19 ft. 8 in. max., above tracks
Size and material	Two copper wires 0.31 in. equiv. diam.	Copper 0.39 in. equiv. diam.	Steel 50 lb. per yd.	Copper 0.29 in. equiv. diam.
Type of collector	Two part sliding bow trolley	Bow pantograph	Vertical sliding shoe	Trolley bow
Transmission voltage	16,000, 3-phase	23,000, 3-phase	8,000, 3-phase	25,000, 3-phase
Contact voltage	750, 3-phase	10,000, single-phase (16⅔ cycles	840, direct	750, direct
Power Generation:				
Owner of plant	Purchased from Kander Station, Bern Power Company	Purchased from Brusio Power Company	Purchased from Canton of Fribourg	Purchased from Brusio Power Company
Number of plants and type	1 hydro-electric	2 hydro-electric	1 hydro-electric	3 hydro-electric
Location	Spiez	Brusio and Robbia	Hauterive near Fribourg	Campo Cologno, Sajento and Robbia
Plant capacity (total, 1-hr. rating)		2,600 kw.		
Number of generators (total)	None	None	None	None
Rating and type		A.C. at 23,000 v.		
Type of prime mover	None	None	None	None
Number of boilers	None	None	None	None
Type	None	None	None	None
Rating (b.h.p.)	None	None	None	None
High Tension Transmission:				
Feeders (circuit miles)—				
On poles (bare wire)	30	None	15	23.53
Underground (insulated cable)	None	None	None	None
Type	3-phase, 40-cycle	3-phase, 50-cycle	3-phase, 50-cycle	3-phase, 50-cycle
Voltage	16,000 a.c.	23,000 a.c.	8,000 a.c.	25,000 a.c.
Substations:				
Number and type	15 static	One motor-generator	2 rotary	4 motor-generator
Average distance apart (miles)	1.63	None	10	10.4
Capacity (total)	2,100 kv-a.	2,600 kv-a.	760 kw.	1,760 kw.
Size of rotary converter units	None	1,300 kw. motor-generator	190 kw.	220 kw. motor-generator
Size of transformer units	140 kw.	1,000 kv-a.	50 kv-a.	440 kv-a.
Rolling Stock:				
Locomotives or motor cars used	Locomotives and motor cars	Locomotives	Motor cars	Motor cars
Number and service	3 locomotives, freight and passenger, 6 motor cars, 14 trailer cars	14 locomotives	4 motor, 7 trailer	17 passenger, 1 freight
Train weight (average) excluding locomotive (tons, 2,000 lb.)	passenger 88, freight 198	60.5-143	None	None
Locomotives:				
Class	(A) 0-4-0 (B) 0-4-4-0	(A) 2-4-2 (B) 2-8-2 (C)	None	
Total weight (tons, 2,000 lb.)	(A) 33.0 (B) 46.2	(A) (B) } 40.4 to 60.9 (C)	None	
Weight on drivers (lb.)	(A) 66,000 (B) 92,400	(A) (B) (C)	None	
Number of motors	2	(A) 1 (B) 2 (C) 2	None	
Type of motor	Geared side-rod drive	(A) (B) Geared side-rod drive (C) Direct side-rod drive	None	
Capacity per motor (h.p., 1-hr. rating)	(A) 150 (B) 250	(A) 300 (B) 300 (C) 400	None	
Tractive effort of locomotive (lb., 1-hr. rating)	(A) 9,930 (B) 7,100	(A) (B) (C)	None	
Normal speed of locomotive (rated load on level track), mi. per hr.	(A) 11.2* (B) 26.1†	(A) 17.5 (B) to (C) 27	None	
Motor Cars:				
Weight excluding passengers (tons, 2,000 lb.)	35.2	None	(A) 36.3 (B) 46.2	30
Seating capacity	66	None	(A) 48 (B) 56	43
Number of motors	4	None	4	4
Capacity per motor (h.p., 1-hr. rating)	60	None	100	75
Trailer Cars:				
Weight excluding passengers (tons, 2,000 lb.)	11-15.4	None	9.9-16.5	9.3
Seating capacity	60	None	32-72	43

* Two speeds, changeable gears.

† Four speeds, changeable poles.

by means of spiral tunnels. When this expedient was proposed it was much criticized, engineers being of the opinion that it would be safer to haul the cars up to the main tunnel on inclined planes. The original plan was adhered to, however, and the line was finally opened for through traffic in June, 1882.

The purposes of the electrification of this road are several. First, it is expected to increase the capacity of the crowded line as the result of an increase in speed, on the heavy grade portions, over that now possible by operation with steam locomotives; second, it is intended to overcome trouble arising from smoke in tunnels which, with the growth of traffic, has become increasingly serious not only in the main tunnel but in the numerous shorter ones; and third, it is estimated that electric operation will effect economies not possible under steam operation because of high cost of coal. Hydro-electric power is available.

Electric locomotives will haul both passenger and freight trains over the entire line. The speed of trains will be increased by the use of electric locomotives of a capacity greater than that of the light steam locomotives at present employed. Plans for the electrification are being made with the intention of using the single-phase alternating current system of traction. Two hydro-electric plants are under construction, one at Amsteg, at the north end of the main tunnel, and the other at Piotto, at the south end. These plants will be initially of 35,000-horse-power capacity each, and either station alone will be capable of handling the entire load. Current will be stepped up to 60,000 volts in the generating stations and transmitted at that voltage, probably by cables, to substations along the line, where it will be stepped down to 15,000 volts and fed to an overhead contact. A preliminary credit of $7,700,000 has been granted by the government for this electrification, and it is expected that the work will be completed in the year 1918.

ITALIAN RAILROAD ELECTRIFICATIONS

205.57 Character of Electrifications in Italy: Examples of heavy electrification in Italy are few in number, but the present situation as regards electric traction in this country is interesting. The first installation of heavy electric traction was completed in 1902 on the Valtellina line, and an important electric interurban line from Milan to Porto Ceresio was completed at about the same time. Both of these installations are operated by the Italian State Railways. These installations were followed by a rapid development in light electric interurban railroad traction throughout the north of Italy, due to the successful operation of these lines. A few years ago the State Railway Administration decided upon an extensive program of electrification, which was inaugurated on the Giovi line now in operation. It is contemplated, under the present plan, to electrify within the next few years more than 1,200 miles of line, or about one-sixth of the total mileage of the Rete Adriatica, about 25 per cent of which has been completed within the last two years. The lines to be electrified and those projected consist, in general, of heavy grade railroads in a mountainous country. The high and continually rising price of coal, which during 1912 averaged about $7.00 a ton, and the numerous opportunities for hydro-electric developments were the influencing factors in the plan. These power developments will be made by private companies with which the government has contracted for the necessary electric energy for the proposed traction requirements.

The following figures show the mileage already electrified:

DIRECT CURRENT	ROUTE MILES	TRACK MILES
Milan-Porto Ceresio	45.50	77.50
THREE-PHASE ALTERNATING CURRENT		
Valtellina	90.40	112.40
Giovi	18.80	54.50
Mt. Cenis (Bussoleno-Modane)	37.00	71.60
Turin-Pinerolo	34.20	44.80
Branches of the Giovi (Succursale di Giovi)	13.60	27.20
Lines around Genoa and the Harbor	.....	37.90
Genoa-Savona	24.80	43.50
Savona-Ceva	31.00	39.60
Total miles of track equipped with three-phase a.c.		431.50
Total miles of track equipped with third rail d.c.		77.50

205.58 Class A — Trunk Line Railroads — Italian State Railways: The Giovi Railway, one of the most important trunk line railroads in Italy, connects Genoa, the greatest shipping center, with Milan, the largest manufacturing city of Italy. The freight traffic on this line is heavy. On the section from Genoa to Busalla the grades are long and heavy, varying from 2.8 per cent to 3.5 per cent in the open and averaging 2.9 per cent in the tunnels. Near the summit of the mountain range is the Giovi tunnel, more than two miles in length. The electrified line includes the portion on the southern slope of the mountains. The road is of double track construction throughout.

Some years ago it was found necessary to relieve the Giovi line of part of its traffic in order to avoid serious congestion and possible demoralization of operation. For this reason a second double track line was built from Campasso, near Genoa, to Ronco. This second line, known as the Succursale di Giovi, was built with much easier grades but with a greater number of tunnels, one of which is five miles in length. The maximum grade is 1.7 per cent, and the line is only one kilometer longer than the old line. The limit of capacity under steam operation on both these lines was reached in 1910, and the necessity for relief became imperative. An increase in the number of tracks was not possible either from a financial or from an engineering viewpoint. Existing legislation limited the speed of steam trains on heavy up-grades to 18.6 miles an hour, while electrically hauled freight trains were permitted to operate at a speed of 28 miles an hour over the same grades. It was therefore decided that electric traction offered the best solution of the problem of increasing the capacity of the line. Recently the second or Succursale di Giovi line was equipped for electric operation.

The Campasso terminal is used principally for freight transferred to steamers, while that at Sampierdarena is used for passenger traffic and local freight. Trains consist normally of 20 cars averaging 19 tons each and are hauled by two electric locomotives, one at the head and one at the rear.

The trains are run on a 15-minute headway during a working day of 18 hours. The locomotives weigh 60 tons each and are equipped with two 1,000-horse-power motors. A speed of 28 miles an hour has been fixed for all up-grade trains with the exception of a few specials. On the down-grade the speed is 28 miles an hour for passenger and 14 miles for freight trains. On the down-grade trip from Busalla to Genoa, the regenerative system of electric braking is used, and trains return from 700 to 1,400 kilowatts to the overhead line.

Power is supplied by a steam power plant located at Genoa on the waterfront of the harbor, while an additional supply is purchased directly. The steam power plant is conveniently located for the delivery of coal in lighters and the use of sea water for the condensers. The equipment consists of two 5,000-kilowatt horizontal turbo-alternators generating three-phase current at 15,000 volts, 15 cycles. Power is transmitted by independent three-phase transmission lines to eight static transformer substations located along both lines. At the substations, the power is stepped down to 3,000 volts, 15 cycles, three-phase, and fed to the overhead contact wires.

The electric traction has proved successful. The limitations of the three-phase system as to speed variation are considered an advantage on a line of this character.

General characteristics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION	
Busalla to Pontedecimo	1910
Pontedecimo to Campasso	1911
Rivarolo to Sampierdarena	1913
Rivarolo to Ronco, and Busalla to Ronco	1914
MILEAGE	
Total route miles	32.4
Total track miles	119.6
TRAIN SERVICE	
Freight	Locomotives
Passenger	Locomotives
AVERAGE NUMBER OF TRAINS DAILY*	
Passenger	12 up-grade 6 down-grade
Freight	20 up-grade 13 down-grade
ELECTRIC TRAIN EQUIPMENT*	
Freight and passenger locomotives	24
TRACTION POWER REQUIREMENTS*	
Maximum load, kw.	5,000
Total per annum, kw-hr.	8,000,000

Certain other portions of the State Railways in Piedmont and Liguria have recently been equipped for electric operation. These include the Genoa-Savona and Savona-Ceva lines and the Mt. Cenis Railway.

The Genoa-Savona and Savona-Ceva lines are sections of the State Railways and in most respects are similar to the Giovi electrification. The Genoa-Savona section, about 25 route miles in length, runs along the Gulf of Genoa between the two cities and has easy grades. The Savona-Ceva line, extending inland about 31 miles from Savona, has 40 miles of track and maximum

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* Does not apply to the Succursale di Giovi.

grades of 2.5 per cent. Electrification was undertaken to relieve congestion and increase the capacity of the road, which had reached its maximum under steam operation. The elimination of smoke in the tunnels was also a controlling factor. These two lines transport all the through traffic for the Province of Piedmont by way of Alessandria. Trains varying from 200 to 600 tons trailing load are hauled by one and three locomotives, respectively, of the Giovi 0–10–0 type. The three-phase system of electric traction similar to that in use on the Giovi, with contact of 3,700 volts, 16⅔ cycles, has been adopted. Power is purchased from a private company which has installed and maintains the five substations and the transmission system. Operation began early in 1914.

The Mt. Cenis Railway is an important line in northern Italy, connecting Turin with points in eastern France by way of the Mt. Cenis Tunnel, and is on the main line from Milan to Paris. The 37-mile electrified section extends from Bussoleno, just west of Turin, to Modane in France, and the ruling grade is about 3 per cent with more than 45 per cent of the road in tunnels. About 22 miles of the section are double tracked. The primary object of electrification was to eliminate smoke in the tunnels and to increase the capacity of the line. About 16 passenger and 32 freight trains are operated daily, at speeds of 30 and 15 miles an hour, respectively. Train weights vary from 200 tons with one locomotive to 600 tons with three locomotives. The locomotives are of the Giovi type. The three-phase system of electric traction with contact potential of 3,300 volts, 16⅔ cycles, is used. At present, power is purchased from the municipality of Milan and is transmitted to the Bardonnecchio substation, where the frequency is reduced to 16⅔ cycles by means of flywheel motor-generator sets and the power distributed to four other substations along the line. Operation began in July, 1912, over the Bardonnecchio-Salbertrand section, and other portions of the line were opened as completed.

The accompanying map, fig. 479, shows the location of the important Italian trunk line electrifications.

205.59 Class A—Trunk Line Railroads—Technical Characteristics: Table CCXXXVII presents a summary of the general and technical characteristics of electrifications of Italian steam railroads included in Class A—Trunk Line Railroads.

205.60 Class B—Secondary Railroads—Italian State Railways: The Turin-Pinerolo Railway is a single track line in the Province of Piedmont. It is about 34 miles long and has a total track mileage of 45. The road is relativly straight and the grades are 1.1 per cent maximum. The three-phase system of traction is used with a working potential of 3,700 volts, 16 cycles. Power is purchased and transmitted to a single substation where the voltage is reduced. Traffic is conducted by locomotive trains.

The Valtellina Railway, the electrification of which was completed in 1902, consists of three divisions forming a "Y," of which Chiavenna and Sondrio represent the upper extremities, Monza the lower point, and Colico the intersection of the three lines. The system embraces about 90 route miles. The mileage of the several branches is as follows:

	MILES
Monza to Lecco	24.40
Lecco to Colico	23.75
Colico to Sondrio	25.50
Sondrio to Chiavenna	16.75

About 50 per cent of the road is located on curves and 30 per cent in tunnels. The heaviest grade is about two per cent and the shortest curve radius is 910 feet.

There were several reasons for the electrification of this line, which was previously operated by steam. Foremost of these were the facts that coal was expensive and that the Italian State Railways controlled numerous water power sites suitable for power generation. The grades and numerous tunnels along the line also made steam operation difficult and objectionable, and it was expected that the absence of smoke in the tunnels and the increased facilities afforded by electric operation would stimulate the tourist traffic.

The road has a heavy summer passenger traffic owing to the fact that the terminals, Chiavenna and Sondrio, connect with the Splügen, Bernina, Stelvio and Maloja Passes, which lead to the Austrian Tyrol and the Engadine. The road also has a large freight traffic in wines, and raw materials for the numerous industries along the line. Both passenger and freight services are handled by motor cars and electric locomotives.

The three-phase, 3,000-volt, alternating current system with double overhead trolley wires is used. Power is generated at the Morbegno hydroelectric station as three-phase current at 20,000 volts, and is transmitted at this voltage to substations in which 3,000-kilovolt-ampere transformers step down the high tension current to the line pressure. The rolling stock consists of 10 motor cars and 15 freight and passenger locomotives. The motor cars weigh about 53 tons equipped, and are capable of hauling from five to seven trailer cars of from ten to twelve tons weight, at a speed of 40 miles an hour on a one per cent grade. The locomotives are of the 0–8–0, 0–10–0 and 2–6–2 types.

The map, presented as fig. 480, shows the location of the electrified lines of the Valtellina Railway.

205.61 Class C—Light Service Railroads—Italian State Railways: The Milan-Porto Ceresio line is a third rail direct current railroad of the interurban class, but it forms an important transportation system between the largest city in northern Italy and numerous suburban towns. It also handles a large excursion business to the lake district. In amount of business conducted and in the speed of its trains, it is regarded in Italy as an important railroad. The road represents one of the pioneer electrifications of the country. It was built by a private company and later taken over by the state. It extends as a double track line from Milan to Gallarate, 25 miles, thence as a single track line for a distance of 20 miles to Porto Ceresio on Lake Lugano. Two single track branches, both operated by steam, leave the line at Gallarate and extend respectively to Laveno and to Arona on Lake Maggiore. About 160 trains a day are operated at a maximum speed of about 56 miles an hour. Until recently all trains consisted of motor and

FIG. 479. ITALIAN TRUNK LINE ELECTRIFICATIONS

TABLE CCXXXVII. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF ITALIAN STEAM RAILROAD ELECTRIFICATIONS, CLASS A—TRUNK LINE RAILROADS

Details	Giovi Railway and Branches	Genoa-Savona-Ceva Railway	Mount Cenis Railway (Bussoleno-Modane)
1	2	3	4
General:			
System of traction	Three-phase alternating current	Three-phase alternating current	Three-phase alternating current
Conductors:			
Type of working conductor	Overhead trolley	Overhead trolley	Overhead trolley
Position	14 ft., 4 in., minimum, 21 ft., 9 in., maximum, above tracks	14 ft., 9 in., minimum, 21 ft., 4 in., maximum, above tracks	14 ft., 9 in., minimum, 21 ft., 4 in., maximum, above tracks
Size and material	2 double copper, 0.44 in. (original installation) equiv. diam., 0.32 in. equiv. diam. (newer lines)	2 double copper, 0.32 in. equiv. diam.	2 double copper, 0.32 in. equiv. diam.
Type of collector	2-part sliding bow trolley	2-part sliding bow trolley	2-part sliding bow trolley
Transmission voltage	15,000, 3-phase	55,000, 3-phase	50,000, 3-phase
Contact voltage	3,000, 3-phase (15 cycles)	3,700, 3-phase ($16\frac{2}{3}$-cycles)	3,300, 3-phase ($16\frac{2}{3}$-cycles)
Power Generation:			
Owner of plant	Railway Company	Purchased	Purchased from Municipality of Turin
Number of plants and type	1 steam-electric*	1 hydro-electric	
Location	Chiappella	S. Dalmazzo di Tenda	
Plant capacity (total, 1-hr. rating)	10,000 kv-a.		
Number of generators (total)	2	None	None
Rating and type	5,000 kw. 15,000 v., 3-phase, 15-cycle	A.C. at 55,000 v.	A.C. at 50,000 v.
Type of prime mover	Steam turbine	None	None
Number of boilers (total)	14	None	None
Type	Water-tube	None	None
Rating (b.h.p.)	400	None	None
High Tension Transmission:			
Feeders (circuit miles)—			
On poles (bare wire)	26.2 (original installation)	119 4	66 0
Underground (insulated cable)	42 2 (newer lines)	None	None
Type	3-phase, 15-cycle	3-phase, $16\frac{2}{3}$-cycle	3-phase, 50-cycle
Voltage	15,000 a.c. (original installation) 27,500 a.c. (newer lines)	55,000	50,000
Substations:			
Number and type	8 static	8 static	1 motor-generator 5 static
Average distance apart (miles)	4 5	7 4	6 2
Capacity (total)	37,200 kv-a.	30,000 kv-a.	18,500 kv-a.
Size of rotary converter units	None	None	
Size of transformer units	750 kv-a. (original installation) 600 kv-a. (newer lines)	750 kv-a.	500 kv-a.
Rolling Stock:			
Locomotives or motor cars used	Locomotives	Locomotives	Locomotives
Number and service	24 freight and passenger		
Train weight (average) excluding locomotives (tons, 2,000 lb.)	380	200—600	200—600
Locomotives:			
Class	0-10-0	0-10-0	0-10-0
Total weight (tons, 2,000 lb.)	60	60	60
Weight on drivers (lb.)	120,000	120,000	120,000
Number of motors	2	2	2
Type of motor	Side-rod drive	Direct side-rod drive	Direct side-rod drive
Capacity per motor (h.p., 1-hr. rating)	1,000	1,000	1,000
Tractive effort of locomotive (lb., 1-hr. rating)	19,500	19,500	19,500
Normal speed of locomotive (rated load on level track), mi. per hr.	28	28	28
Motor Cars:			
Weight excluding passengers (tons, 2,000 lb.)	None	None	None
Seating capacity	None	None	None
Number of motors	None	None	None
Capacity per motor (h.p., 1-hr. rating)	None	None	None
Trailer Cars:			
Weight excluding passengers (tons, 2,000 lb.)	None	None	None
Seating capacity	None	None	None

* Power also purchased at 27,500 volts and 15 cycles.

trailer cars, operated on the multiple-unit system, but several 79-ton locomotives of the 2–6–2 type have now (1914) been acquired and are used for passenger traffic. Power is purchased from the Cairasca hydro-electric plant at Varzo near the Simplon tunnel and is transmitted to the substations via Milan. Substations along the railroad transform and convert the power to 650-volt direct current, which is fed into the third rails in the usual manner.

The operation of this road was begun in the year 1901. The electrification now comprises 45.5 route miles and the equipment consists of 6 locomotives, 41 motor cars and 80 trailers.

The map presented as fig. 481 shows the location of the electrified lines of the Milan-Porto Ceresio Railway.

205.62 Classes B and C—Secondary and Light Service Railroads—Technical Characteristics: Table CCXXXVIII presents a summary of the general and technical characteristics of electrifications of Italian steam railroads included in Classes B and C—Secondary and Light Service Railroads.

AUSTRIAN RAILROAD ELECTRIFICATIONS

205.63 Character of Electrifications in Austria: No standard gage trunk line electrifications have

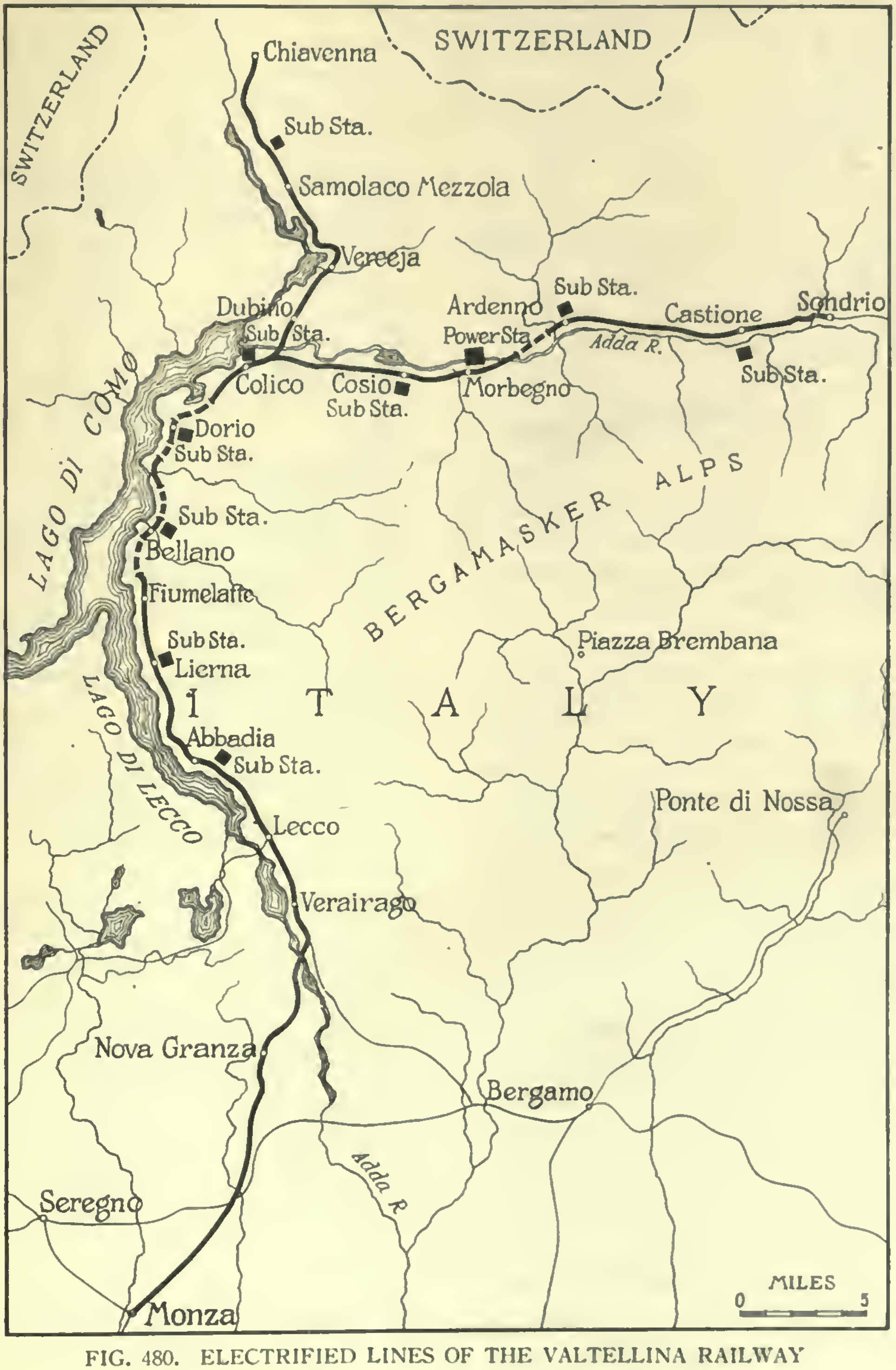

FIG. 480. ELECTRIFIED LINES OF THE VALTELLINA RAILWAY

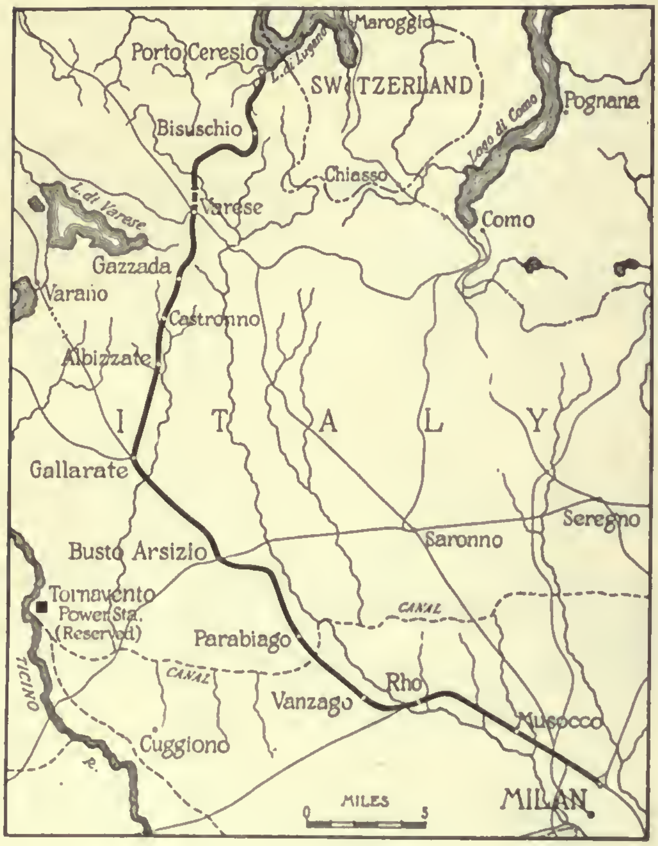

FIG 481. ELECTRIFIED LINES OF THE MILAN-PORTO CERESIO RAILWAY

as yet been undertaken in Austria. A number of narrow gage electric railroads partaking of the character of interurban lines are in operation, and in some cases these roads conduct a fairly heavy train service over lines with many grades and sharp curves. The business consists largely of passenger traffic, although in some cases a limited amount of freight is handled. The Government Railway Administration has had electric traction under consideration for a number of years for certain portions of the trunk lines, but construction has been deferred for various reasons, among them being the difficulties of financing and objections of the War Department because of the problem of protecting electric construction in case of war. The projects which will probably be carried out first are the electrification of the Arlberg Tunnel line and that of the high speed line from Vienna to Brunn, a distance of about 90 miles. As regards electric systems, all roads of any considerable length employ the single-phase high tension current system.

TABLE CCXXXVIII. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF ITALIAN STEAM RAILROAD ELECTRIFICATIONS, CLASSES B AND C—SECONDARY AND LIGHT SERVICE RAILROADS

Details	Milan-Porto Ceresio Railway Class C	Valtellina Railway Class B
General:		
System of traction	Low tension direct current	Three-phase alternating current.
Conductors:		
Type of working conductor	Third rail	Overhead trolley.
Position	Over running	19 ft., 8½ in., max. 15 ft., 8½ in., minimum above tracks
Size and material	Steel 90.7 lb. per yard	Copper 0.31 in. equiv. diameter.
Type of collector	Cast iron link shoe.	Two part roller bow trolley
Transmission voltage	50,000, 3-phase	20,000, 3-phase
Contact voltage	650 d c	3,000, 3-phase
Power Generation:		
Owner of plant	Railway Company	Railway Company
Number of plants and type	1 steam-electric	1 hydro-electric
Location	Tornavento*	Morbegno
Plant capacity (total, 1-hr. rating)	2,250 kv-a	4,500 kv-a
Number of generators (total)	3	3
Rating and type	750 kw., 13,200-v. 3-phase, 25-cycle.	1500 kw., 20,000-v. 3-phase, 15-cycle
Type of prime mover	Steam engine	Hydraulic turbines
Number of boilers (total)	8	None
Type	Water-tube.	None
Rating b.h.p.	310	None
High Tension Transmission:		
Feeders (circuit miles)—		
On poles (bare wire)	31.2	66.0
Underground (insulated cable)	None	None
Type	3-phase, 42-cycle.	3-phase, 15-cycle.
Voltage	50,000 a. c	20,000 a.c.
Substations:		
Number and type	7 rotary	11 static
Average distance apart (miles)	4 5	
Capacity (total)	14,000 kw	3,300 kv-a
Size of rotary converter units	1,000 kw	None
Size of transformer units	1,100 kv-a	300 kw
Rolling Stock:		
Locomotives or motor cars used	Motor cars and locomotives	Locomotives and motor cars
Number and service	41 motor, 80 trailer 1 freight locomotive, 6 freight and passenger locomotives	10 motor cars, 15 locomotives
Train weight, average, excluding locomotive (tons, 2,000 lb.)	220 passenger, 410 freight	160 passenger, 400 freight
Locomotives:		
Class	(A) 0-8-0 (B) 2-6-2	(A) 0-8-0 (B) 2-6-2 (C) 0-10-0
Total weight (tons, 2,000 lb.)	(A) 38.50 (B) 78.65	(A) 46 (B) 62 (C) 60
Weight on drivers (lb.)	(A) 77,000 (B) 99,000	(A) 92,000 (B) 84,000 (C) 120,000
Number of motors	(A) 4 (B) 2	(A) 4 (B) 2 (C) 2
Type of motor	(A) geared (B) side-rod drive	(A) gearless (B & C) side-rod drive
Capacity per motor (h.p., 1-hr. rating)	(A) 150 (B) 1,000	(A) 150 (B) 600 (C) 1,000
Tractive effort of locomotive (lb., 1-hr. rating)	(A) 8,800 (B) 19,800	(A) 14,400 (B) 24,360 (C) 19,500
Normal speed of locomotive (rated load on level track), mi. per hr.	(A) 24.8 (B)	(A) 20 (B) 20-40 (C) 14-28
Motor Cars:		
Weight excluding passengers (tons, 2,000 lb.)	(A) 45.1 (B) 49.5 (C) 58.3	53
Seating capacity	(A) 73 (B) 80 (C) 40	(A) 56 (B) 40
Number of motors	(A) 4 (B) 2 (C) 4	4
Capacity per motor (h.p., 1-hr. rating)	150	150
Trailer Cars:		
Weight excluding passengers (tons, 2,000 lb.)	30	20
Seating capacity	90	90

* Reserve steam plant. Power now (1914) purchased from Cairasca power plant at Varzo, Italy.

FIG. 482. ELECTRIFIED LINES OF THE ST. PÖLTEN-MARIAZELL-GUSSWERK RAILWAY

205.64 Class B—Secondary Railroads—St. Pölten-Mariazell-Gusswerk Railway: The St. Pölten-Mariazell-Gusswerk Railway is a narrow gage line of the Austrian State Railways, comprising about 57 miles of single track. The road has numerous grades as heavy as 2.5 per cent, many tunnels and a large amount of curvature. Electrification of this road, which was previously operated by steam, was undertaken for the purpose of increasing its capacity, the limit of which had been reached under steam operation. The traffic consists largely of passenger service and includes a heavy excursion business during a portion of the year. Operation is effected by electric locomotives, of which 16 are in use for both passenger and freight service. The system of traction employs single-phase alternating current at 6,500 volts with overhead trolley. Power is purchased from a hydro-electric plant and a reserve gas-electric station is used during the seasons of low water.

The map, presented as fig. 482, shows the location of the electrified lines of the St. Pölten-Mariazell-Gusswerk Railway.

TABLE CCXXXIX. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF AUSTRIAN STEAM RAILROAD ELECTRIFICATIONS, CLASS B—SECONDARY RAILROADS

Details	St. Pölten-Mariazell-Gusswerk Railway
General:	
System of traction	Single-phase alternating current
Conductors:	
Type of working conductor	Overhead trolley
Position	18 ft., ½ in., maximum, 12 ft., 1 in., minimum above track
Size and material	Copper 0.39 in. equiv. diam.
Type of collector	Sliding bow trolley
Transmission voltage	27,000, single-phase
Contact voltage	6,500, single-phase
Power Generation:	
Owner of plant	Province of Lower Austria
Number of plants and type	1 hydro-electric 1 gas-electric (reserve)*
Location	Wienerbruck
Plant capacity (total, 1-hr. rating)	4,500 kv-a.
Number of generators (total)	14
Rating and type	3–900 kv-a.–6,500 v. (single-phase rating) 1–1,800 kv-a.–6,500 v. (three-phase, 25-cycle)
Type of prime mover	Hydraulic turbines
Number of boilers (total)	None
Type	None
Rating (b.h.p.)	None
High Tension Transmission:	
Feeders (circuit miles)—	
On poles (bare wire)	38.6
Underground (insulated cable)	None
Type	Single-phase, 25-cycle
Voltage	27,000 a. c.
Substations:	
Number and type	2 static †
Average distance apart (miles)	12
Capacity (total)	1,800 kv-a
Size of rotary converter units	None
Size of transformer units	900 kv-a
Rolling Stock:	
Locomotives or motor cars used	Locomotives
Number and service	16 passenger and freight
Train weight (average) excluding locomotive (tons, 2,000 lb.)	110
Locomotives:	
Class	0–6–6–0
Total weight (tons)	49.5
Weight on drivers (lb.)	99,000
Number of motors	2
Type of motors	Geared side-rod drive
Capacity per motor (h.p., 1-hr. rating)	300
Tractive effort of locomotive (lb., 1-hr. rating)	15,400
Normal speed of locomotive (rated load on level track), mi. per hr.	17.3
Motor Cars:	
Weight excluding passengers (tons, 2,000 lb.)	None
Seating capacity	None
Number of motors	None
Capacity per motor (h.p., 1-hr. rating)	None
Trailer Cars:	
Weight excluding passengers (tons, 2,000 lb.)	None
Seating capacity	None

* St. Pölten power station contains 2-700 kv-a, 3-phase, 25-cycle generators.

† Also a 6,500-volt feeder to line from power station.

205.65 Class B — Secondary Railroads — Vienna-Pressburg Railway: This is a composite direct and alternating current railroad operating from Vienna to Pressburg, a distance of 42 miles. In the city terminals and suburbs of Vienna and Pressburg, the railroad is equipped with a 600-volt, direct current overhead trolley and, in the mid-section between the cities, high tension alternating current with overhead contact is employed. The train service is light. Locomotives are used for both freight and passenger trains.

The map, presented as fig. 483, shows the location of the electrified lines of the Vienna-Pressburg Railway.

205.66 Class B — Secondary Railroads — Technical Characteristics: Table CCXXXIX presents a summary of the general and technical characteristics of electrifications of Austrian steam railroads included in Class B — Secondary Railroads.

HOLLANDISH RAILROAD ELECTRIFICATIONS

205.67 Class B — Secondary Railroads — Holland Railway — Rotterdam-Hague-Scheveningen: This is a double track railroad extending from the city of Rotterdam to The Hague, 16 miles, and to the seashore resort of Scheveningen, 4.4 miles from The Hague. It enters Rotterdam over a heavy concrete viaduct 1.25 miles long, and the construction of the roadway is substantial throughout.

The railroad was constructed for the purpose of handling a large interurban and excursion traffic by frequent and rapid train service. Electric traction was thought to be an essential factor in attracting the class of traffic desired.

Passenger traffic only is handled and express and local trains are run frequently. The first season after the road was opened 52 trains a day were run between The Hague and Rotterdam in an average running time of 23 minutes. The train service during the Scheveningen bathing season calls for 144 trains a day and, with the limited equipment, requires an average of 357 car-miles a day for each motor car.

In 1900 a contract was entered into by the original promoters for the construction of an 850-volt, direct current railroad, generating power at 10,000-volts, three-phase, and transmitting it to two rotary converter substations. Later the railroad was taken over by other interests and, after considerable delay caused by the difficult problems presented in the way of roadway construction, it was thought best to change to the single-phase system with a supported overhead catenary conductor.

General statistics of this electrification are as follows:

DATE OF INITIAL ELECTRIC OPERATION, OCT., 1908

MILEAGE	
Total route miles	20.4
Total track miles	47.5
TRAIN SERVICE	
Passenger	Motor cars
AVERAGE NUMBER OF CARS PER TRAIN	
Passenger	2
AVERAGE NUMBER OF TRAINS DAILY (BOTH WAYS)	
Passenger	144 summer 90 winter
ELECTRIC TRAIN EQUIPMENT	
Motor cars	21
Trailer cars	17
Locomotives (storage battery, for testing and switching)	2

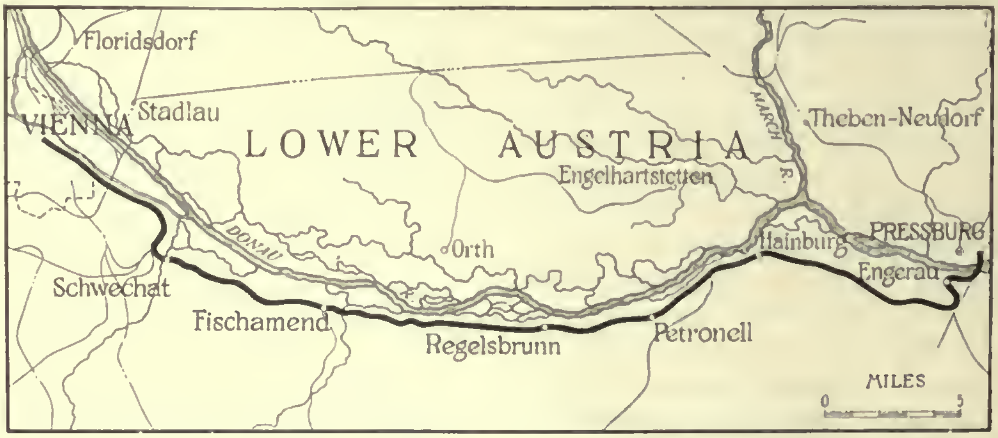

FIG. 483. ELECTRIFIED LINES OF THE VIENNA-PRESSBURG RAILWAY

TRAIN-MILES PER ANNUM (1913)	
Passenger	632,400
CAR-MILES PER ANNUM (1913)	
Passenger	1,258,600
TRACTION POWER REQUIREMENTS (1913)	
Maximum load, kw.	3,000
Total per annum, kw-hr.	5,436,000

The accompanying map, fig. 484, shows the location of the electrified lines of the Holland Railway.

FIG. 484. ELECTRIFIED LINES OF THE HOLLAND RAILWAY
(Rotterdam-Hague-Scheveningen)

205.68 Class B — Secondary Railroads — Technical Characteristics: Table CCXL presents a summary of the general and technical characteristics of electrifications of Dutch steam railroads included in Class B — Secondary Railroads.

NORWEGIAN AND SWEDISH RAILROAD ELECTRIFICATIONS

205.69 Character of Electrifications in Norway and Sweden: Much interest is being exhibited in Norway and Sweden in the subject of railroad electrification, due to the fact that there exist many possibilities for the development of hydro-electric power plants, while coal for steam locomotive fuel must be imported and is expensive. A number of large hydro-electric plants have already been established, primarily for electro-chemical industries, and power from these plants is available for electric railroads.

205.70 Class B — Secondary Railroads — Rjukan Railway (Norway): The Rjukan Railway in southern Norway was built in 1908 and operated as a steam line until 1911 when it was equipped for electric operation. It is a standard gage single track line operated chiefly in the interests of the extensive saltpetre industries at Saaheim. One section of the railroad extends from Saaheim to Vestfjorddalen, on the banks of the Tinnsjo Lake, whence traffic is handled by transfer steamers for a distance of 15 miles to Tinnoset. From Tinnoset the road continues for a distance of about 19 miles to its terminus at Notodden. From this latter point extensions to the south are under construction. Over the

TABLE CCXL. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF DUTCH STEAM RAILROAD ELECTRIFICATIONS, CLASS B—SECONDARY RAILROADS

Details	Holland Railway (Rotterdam-Hague-Scheveningen)
General:	
System of traction	Single-phase alternating current
Conductors:	
Type of working conductor	Overhead trolley
Position	18 ft. above track
Size and material	Copper 0.44 in. equiv. diam.
Type of collector	Sliding bow trolley
Transmission voltage	10,000, single-phase
Contact voltage	10,000, single-phase
Power Generation:	
Owner of plant	Railway Company
Number of plants and type	1 steam-electric
Location	Leidschendam
Plant capacity (total, 1-hr. rating)	5,700 kv-a.
Number of generators (total)	4
Rating and type	2–850 kv-a. 2–2,000 kv-a. 5,000-v. 3-phase, 25-cycle
Type of prime mover	Steam engines Steam turbines
Number of boilers (total)	5
Type	
Rating (b.h.p.)	270
High Tension Transmission:	
Feeders (circuit miles)—	
On poles (bare wire)	9.5 (est.)
Underground (insulated cable)	None
Type	Single-phase, 25-cycle
Voltage	10,000 a.c.
Substations:	
Number and type	None
Average distance apart (miles)	None
Capacity (total)	None
Size of rotary converter units	None
Size of transformer units	None
Rolling Stock:	
Locomotives or motor cars used	Locomotives and motorcars*
Number and service	2 locomotives, 21 motor cars, 17 trailers
Train weight (average) excluding locomotive (tons, 2,000 lb.)	None
Locomotives:	
Class	
Total weight (tons, 2,000 lb.)	
Weight on drivers (lb.)	
Number of motors	
Type of motor	
Capacity per motor (h.p., 1-hr. rating)	
Tractive effort of locomotive (lb. 1-hr. rating)	
Normal speed of locomotive (rated load on level track), mi. per hr	
Motor Cars:	
Weight excluding passengers (tons, 2,000 lb.)	56.7
Seating capacity	56
	73
Number of motors	2
Capacity per motor (h.p., 1-hr. rating)	180
Trailer Cars:	
Weight, excluding passengers (tons, 2,000 lb.)	34.1
Seating capacity	88

* Storage battery locomotives used for switching and testing purposes.

entire distance southbound traffic meets descending grades varying from 1.8 to 2.7 per cent.

The reasons given for this electrification are:

1. The availability of cheap hydro-electric power generated at the large electro-chemical works near Saaheim.

2. The necessity of increasing the capacity of the line and of avoiding smoke in tunnels.

3. The necessity of preventing forest fires originating from the stack discharges of steam locomotives.

The traffic on this road consists almost entirely of freight. The light passenger traffic is handled by adding one or two trailer cars to the freight trains. These trains average 320 tons in weight and are hauled by a 500-horse-power electric locomotive. On the three-mile section out of Notodden, on which the grade is 2.7 per cent, two locomotives per train are used. The amount of freight carried down-grade is nearly double that carried up-grade, including about 150,000 tons per annum of raw materials for the saltpetre works and 40,000 tons of general merchandise.

The traction system employs single-phase alternating current at 10,000 volts, 15 cycles, with an overhead trolley line. Power is generated at a hydro-electric station at Rjukanfos. When finally completed this station will be one of the largest in the world, being designed to develop 250,000 horsepower. There will be 10 generating units of 17,000 kilovolt-amperes each, the power from which will be used principally for the chemical industries. Power is generated as three-phase current at 10,000 volts and 50 cycles and, for traction requirements, is transmitted to converter substations containing transformers and motor-generator sets, where it is converted into single-phase current at the proper frequency for traction.

General statistics of this electrification are:

DATE OF INITIAL ELECTRIC OPERATION, 1911

Total route miles	28.6
Total track miles	28.6
Train service	Locomotives
Number of locomotives	5

The accompanying map, fig. 485, shows the electrified lines of the Rjukan Railway.

205.71 Class C — Light Service Railroads — Thamshavn-Lökken Railway (Norway): The Thamshavn-Lökken Railway is a short single track, narrow gage line in central Norway, extending

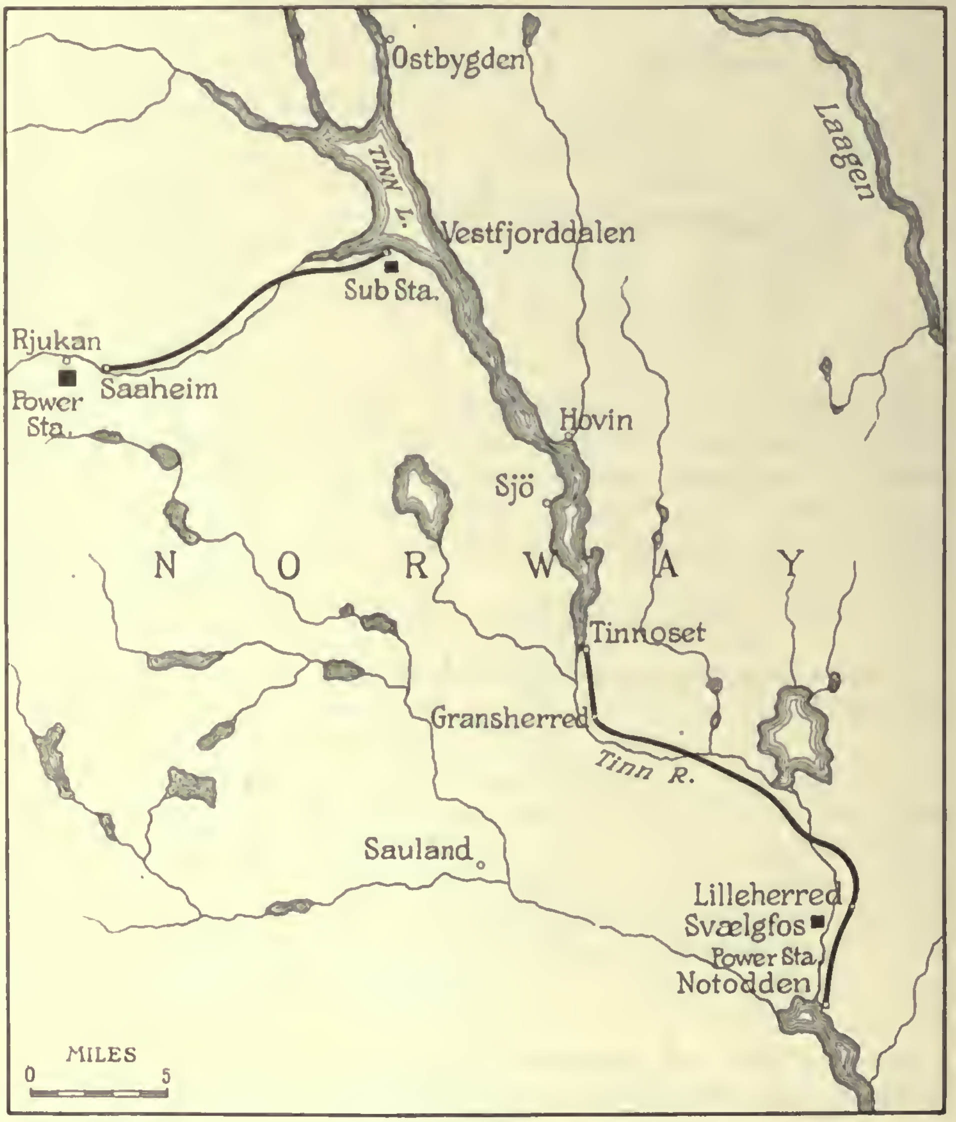

FIG. 485. ELECTRIFIED LINES OF THE RJUKAN RAILWAY

from Thamshavn along the Orkla River to Svorkmo and thence inland to the copper and sulphur mines at Lökken. The railroad is of one-meter gage and has easy gradients from Thamshavn to Svorkmo. From the latter point the road rises rapidly to Lökken with sharp curves and gradients as heavy as 4.0 per cent. A steamer service connects Thamshavn with Trondhjem, at which point a number of roads connect with the southern and eastern portions of the country. The lumber mills at Thamshavn and the mines at Lökken provide a considerable freight traffic, while the scenic beauty of the district attracts many tourists. This road has been electrified for both freight and passenger service. It was opened in July, 1908, and is the first example of the equipment of a Norwegian road for electric operation.

The object of electrification was to effect a saving in operating expense by the substitution of hydro-electric power for power from expensive imported coal, and also to determine experimentally the technical features of electric traction as adapted to heavy train units.

Both freight and passenger trains are hauled by electric locomotives. The passenger trains consist generally of only two cars. The freight trains have a maximum weight of 150 tons. The speeds vary, according to the grades encountered, from 10 to 20 miles an hour for both classes of service.

The single-phase, 25-cycle, 6,600-volt alternating current system with overhead trolley has been adopted. Power is generated in a hydro-electric plant at Skjenald Falls, six miles west of Thamshavn, as three-phase current at 1,000 volts, is stepped up to 15,000 volts and is transmitted to a substation at Thamshavn where it is converted to single-phase current at 6,600 volts and fed into the line. The rolling equipment consists at present of three 22-ton electric locomotives and a motor car for special service.

The accompanying map, fig. 486, shows the location of the electrified lines of the Tham-shavn-Lökken Railway.

FIG. 486. ELECTRIFIED LINES OF THE THAMSHAVN-LÖKKEN RAILWAY

205.72 Classes B and C—Secondary Railroads—Technical Characteristics: Table CCXLI presents a summary of the general and technical characteristics of electrifications of Norwegian steam railroads as follows: Rjukan Railway, Class B, and Thamshavn-Lökken Railway, Class C.

205.73 Electrification Projects in Norway and Sweden under Construction or in Contemplation:* The Kiruna-Riksgränsen Railway is a normal gage single track steam road in northern Sweden. It is used chiefly to haul iron ore from the mines at Kiruna to the coast. The northern terminus lies near the boundary line between Norway and Sweden. Connections are made at this point with a Norwegian line which runs to Narvik, practically the only harbor within the Arctic Circle open to navigation during the entire year. From Riksgränsen the line runs south through a mountainous region, skirting Lake Torne Trask and ending at Kiruna, a total distance of 80 miles. The line has many long grades and tunnels. Snow and ice form troublesome obstacles to traffic during the greater part of the year.

Cheap hydro-electric power and expensive coal, together with the need of an increase in the capacity of the railroad for handling the output of the Kiruna mines, were the controlling reasons in the decision to adopt electric traction. When the electrification is completed the ore freight trains will be made up of two electric locomotives and 40 cars. Each car will weigh 51 tons loaded. The average speed will be 22 miles an hour. The single-phase system of electric traction will be used and the current will be supplied from the hydro-electric station now under construction at

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*1914.

TABLE CCXLI. SUMMARY OF GENERAL AND TECHNICAL CHARACTERISTICS OF NORWEGIAN STEAM RAILROAD ELECTRIFICATIONS, CLASSES B AND C—SECONDARY RAILROADS

Details	Thamshavn-Lökken Railway	Rjukan Railway
General:		
System of traction	Single-phase alternating current	Single-phase alternating current
Conductors:		
Type of working conductor	Overhead trolley	Overhead trolley
Position	18 ft., 5 in., above track	14 ft.,9 in.,minimum 18 ft.,0 in.,maximum above track
Size and material	Copper 0.35 in. equiv. diameter	Copper 0.35 in. equiv. diameter
Type of collector	Bow pantograph	Bow pantograph
Transmission voltage	15,000 three-phase,	10,000 three-phase
Contact voltage	6,600 single-phase	10,000 single-phase
Power Generation:		
Owner of plant	Railway Company	Railway Company
Number of plants and type	1 hydro-electric	1 hydro-electric *
Location	Skjenald Fossen	Rjukanfos
Plant capacity (total, 1-hr. rating)	2,725 kv-a	170,000 kv-a
Number of generators (total)	5	10
Rating and type	545 kv-a., 1,000-v. 3-phase, 50-cycle.	17,000 kv-a. 10,000-v. multiphase, 50-cycle
Type of prime mover	Hydraulic turbines.	Hydraulic turbines
Number of boilers (total)	None	None
Type	None	None
Rating (b. h. p.)	None	None
High Tension Transmission:		
Feeders (circuit miles)—		
On poles (bare wire)	6 (est.)	
Underground (insulated cable)	None	3-phase, 50-cycle
Type	3-phase, 50-cycle	10,000 a. c.
Voltage	15,000 a.c	
Substations:		
Number and type	1 motor-generator	2 motor-generators
Average distance apart (miles)	None	
Capacity (total)	500 kv-a	2,000 kv-a
Size of rotary converter units	2-250 kv-a. (motor-generator)	5-400 kv-a. (motor-generator)
Size of transformer units	250 kv-a	400 kv-a
Rolling Stock:		
Locomotives or motor cars used	Locomotives and motor cars	Locomotives
Number and service	3 locomotives, passenger and freight, 1 motor car (special car), 4 trailers	5 locomotives
Train weight (average) excluding locomotive (tons, 2,000 lb.)	150 passenger and freight	319 (2 locomotives on maximum grade)
Locomotives:		
Class	0-4-4-0	(A) 0-4-0 (B) 0-4-4-0
Total weight (tons)	22	(A) 23 (B) 44
Weight on drivers (lb.)	44,000	(A) 46,000 (B) 88,000
Number of motors	4	(A) 2 (B) 4
Type of motor	Geared	(A) Gearless (B) Geared
Capacity per motor (h.p., 1-hr. rating)	40	125
Tractive effort of locomotive (lb., 1-hr. rating)	6,600	(A) (B) 19,650
Normal speed of locomotive (rated load on level track) mi. per hr.	11.2	15
Motor Cars:		
Weight excluding passengers (tons, 2,000 lb.)	23	None
Seating capacity		None
Number of motors	2	None
Capacity per motor (h.p., 1-hr. rating)	40	None
Trailer Cars:		
Weight excluding passengers (tons, 2,000 lb.)		None
Seating capacity		None

* Also supplies power for mines and other purposes.

Porjus. For traction purposes single-phase current will be generated at 4,000 volts, stepped up to 80,000 volts for transmission to four transformer substations, each of about 6,000-kilowatts capacity. The contact line potential will be 15,000 volts. Thirteen freight and two passenger locomotives are under construction. The former will be of the two part interchangeable type. They will weigh 150 tons each and are to be equipped with two 1,000-horse-power motors. Each passenger locomotive will have a single 1,000-horse-power motor of about the same type and will weigh about 92 tons equipped. When the electrification is completed, it is contemplated that the iron mines will increase their output to 3,500,000 tons per year.

General statistics of this proposed electrification are as follows:

MILEAGE	
Total route miles	80
Total track miles	93
TRAIN SERVICE	
Passenger	Locomotives
Freight	Locomotives
AVERAGE NUMBER OF CARS PER TRAIN	
Freight	40
AVERAGE NUMBER OF TRAINS DAILY	
Freight	12
ELECTRIC TRAIN EQUIPMENT	
Locomotives, passenger	2
Locomotives, freight	13
TRACTION POWER REQUIREMENTS	
Total per annum, kw-hr. (est.)	35,000,000

AUSTRALIAN RAILROAD ELECTRIFICATIONS

205.74 Australian Electrification Projects under Construction or in Contemplation (1914): The state of Victoria lies along the southern coast of the Commonwealth of Australia. The city of Melbourne is its capital, with a population of 500,000, or about 40 per cent of the total population of the state. The area of the city is so great, however, that the actual congestion is less than that found in most other large cities, the population within the boundaries of the city of Greater Melbourne being only 2,000 per square mile as compared with 9,600 in London and 12,000 in New York. Owing to this condition, a large portion of the population of Melbourne must travel a considerable distance to reach the business center. This fact has resulted in a very complete development of suburban transportation facilities.

The suburban steam railroads carry more than 50 per cent of the combined city traffic and furnish 40 per cent of the total passenger receipts for the whole Victorian railroad system. All railroads of the state, including the Melbourne suburban system, are owned by the Victorian Government, but the local tramway system of the city, operated mostly by cable and comparatively limited in its scope, is operated under a private franchise which will soon expire. At the expiration of the franchise it is probable that the tramway system will be taken over by the city or state and electrified. The lines of the Melbourne suburban system of the Victorian Railway comprise a network with many short radiating lines. The mileage of the lines included in the electrification plan consists of 150 route miles, or 289 track miles of main line and 34 miles of sidings.

The electrification project now in progress had its inception in a report made in 1908 to the Victorian Railway Commission, recommending that electrification be undertaken in three stages in order that experience might be gained with reference to both technical and financial features, but for a number of reasons the matter was deferred until 1912. In that year it was found that the suburban traffic was increasing beyond expectations and the opinion now prevails that electrification is necessary. Plans have been made to conduct both passenger and freight service by electrically operated trains, but at present the only details available relate to passenger traffic, which is of the greater importance on a line of this character. Passenger trains are to consist normally of two motor cars and two trailers, weighing together about 180 tons. During rush hours the trains may be increased to a maximum of six cars each, and it is expected that the number of passenger trains will be increased and the average weight of the trains reduced as compared with the trains at present handled by steam locomotives. The cars will be new and of the corridor type. About 500 motor cars and 450 trailers are to be ordered. Each motor car is to be equipped with four 140-horse-power motors.

The question of the choice of an electric system for this suburban electrification has been made the subject of very full consideration. The conclusion presented in reports to the Commission, and based upon bids received from the various electric companies for apparatus, recommended the 1,500-volt direct current trolley system as being cheaper, both in installation and operating costs, than the single-phase alternating current system. The former system was accordingly adopted. Power is to be generated in a centrally located steam power plant as three-phase alternating current at 25 cycles and transmitted at 20,000 volts potential to twelve substations located along the lines, where it will be transformed and converted into direct current to be fed into the trolley wires. The full electric equipment of the entire system will probably be completed by 1917. The installation will involve the expenditure of about $13,500,000.

General characteristics of this proposed electrification are as follows:

MILEAGE		
Total route miles		150.28
Total track miles	289.30	
Total siding miles	34.64	
Total miles of electrically equipped track		323.94
TRAIN SERVICE		
Passenger		Motor and trailer cars
AVERAGE NUMBER OF CARS PER TRAIN		
Passenger		4.48
ELECTRIC TRAIN EQUIPMENT		
Motor cars		500
Trailer cars		450
TRAIN-MILES PER ANNUM		
Passenger		8,500,000
CAR-MILES PER ANNUM		
Passenger		38,000,000
TRACTION POWER REQUIREMENTS		
Total per annum, kw-hr.		129,262,000

206. A COMPARATIVE STUDY OF STEAM RAILROAD ELECTRIFICATION PROJECTS

SYNOPSIS: The magnitude and importance of the proposed electrification of the Chicago railroad terminals may be judged by comparing the conditions and requirements in Chicago, with those of existing electrifications elsewhere. Comparisons are made in this chapter with respect to the number of railroads involved, their trackage, nature of traffic, power requirements and equipment. A summary of the character, influences and purposes of existing electrifications is presented and the relation of such considerations to the Chicago situation is shown.

206.01 The Number of Steam Railroads which have Resorted to Electric Operation: The significance of the proposal to operate electrically the railroad terminals of Chicago is suggested by the fact that the number of railroads included by the Chicago terminals is equal to the total number involved in all existing steam railroad electrifications in the entire world. A comparison between the number of roads involved in the Committee's plan of electrification in Chicago and the number of existing electrifications elsewhere is presented by table CCXLII.

TABLE CCXLII. NUMBER OF EXISTING STEAM RAILROAD ELECTRIFICATIONS COMPARED WITH THE NUMBER OF ROADS INVOLVED IN THE PROPOSED ELECTRIFICATION IN CHICAGO

Classes	American Railroads	Foreign	Total American and Foreign	Chicago
1	2	3	4	5
Trunk lines	10	12	22	23
Trunk lines owning track	10	....	.....	22
Transfer and switching railroads	.....	....	..	14
Total number of railroads concerned, not including foreign secondary lines with light service	15	22	37	37

206.02 Extent of Existing Steam Railroad Electrified Trackage Compared with the Trackage of the Chicago Terminals: Another measure of the importance of any electrification project is that presented by the extent of its track. The mileage of track involved by the proposed electrification of the Chicago railroad terminals is nearly twice as great as the mileage of all existing electrically operated steam railroad track in America to-day and, exclusive of foreign light service lines, is about 15 per cent greater than the combined total mileage of all existing electrically operated steam railroad track in the entire world. The Committee's plan of electrification involves several times as much yard track mileage as do all existing electrifications on American railroads. A more detailed comparison of the mileage of American and foreign electrified trackage with that of the Chicago terminals is set forth by the summary immediately following, and by tables CCXLIII to CCXLVI, inclusive.

	TOTAL MILES OF TRACK
Existing American electrifications	1,729
Existing foreign electrifications, excluding secondary lines	1,278
Combined American and foreign electrifications . .	3,007
Proposed electrification in Chicago	3,439

TABLE CCXLIII. MILEAGE INVOLVED BY STEAM RAILROAD ELECTRIFICATIONS

Classes	Existing Electrifications on American Lines	Existing Electrifications on Foreign Trunk and Heavy Secondary Lines	Total Mileage of Existing American and Foreign Electrifications for Heavy Traffic	Proposed Electrification in Chicago
1	2	3	4	5
Route miles	597	724	1,321	565.20
Miles of main track	1,275	1,045	2,320	1,475.59
Miles of other track	454	233	687	1,963.55
Total miles of track	1,729	1,278	3,007	3,439.14

206.03 Density of Traffic on Existing Electrified Steam Railroads Compared with that of the Chicago Terminals: Facts set forth by a study of the traffic requirements of existing electrically operated steam railroads and those of the Chicago terminals serve to indicate the relative magnitude of the proposed electric operation in Chicago. Such a comparison presents the following significant conditions:

1. The number of through passenger trains required by the traffic of the Chicago terminals is 85 per cent of the total number of such trains at present operated electrically on all American steam railroads.

TABLE CCXLIV. AMERICAN STEAM RAILROAD ELECTRIFICATIONS. MILEAGE BY CLASSES

Classes	Route Miles	Miles of Main Track	Miles of Other Track	Total Miles of Track
1	2	3	4	5
CLASS I —TERMINAL LINES				
Long Island Railroad	88.63	187.08	20.89	207.97
New York Central & Hudson River Railroad	52.60	177.00	67.60	244.60
New York, New Haven & Hartford Railroad	76.57	329.38	202.30	531.68
Pennsylvania Railroad	18.73	46.73	50.76	97.49
Totals	236.53	740.19	341.55	1,081.74
CLASS II —MAIN LINES				
West Jersey & Seashore Railroad	74.60	147.80	2.46	150.26
Spokane & Inland Empire Railroad	127.00	129.50	1.50	131.00
Butte, Anaconda & Pacific Railway	30.40	30.40	60.10	90.50
Totals	232.00	307.70	64.06	371.76
CLASS III —SUBURBAN LINES				
Erie Railroad	34.00	34.00	4.00	38.00
Southern Pacific Railroad	52.25	100.81	14.00	114.81
New York, Westchester & Boston Railway	18.23	49.60	3.96	53.56
Totals	104.48	184.41	21.96	206.37
CLASS IV —TUNNEL LINES				
Baltimore & Ohio Railroad	3.70	7.40	1.00	8.40
Grand Trunk Western Railway	3.80	6.50	5.50	12.00
Great Northern Railway	4.00	4.00	3.00	7.00
Michigan Central Railroad	4.50	9.00	11.00	20.00
Boston & Maine Railroad	7.97	15.94	5.56	21.50
Totals	23.97	42.84	26.06	68.90
Grand totals, America	596.98	1,275.14	453.63	1,728.77
Mileage to be electrified in Chicago	565.20	1,475.59	1,963.55	3,439.14

2. The number of suburban passenger trains required by the traffic of the Chicago terminals is approximately one-half the number of such trains at present operated electrically on all American steam railroads.

3. The passenger train-miles in both through and suburban service for the Chicago terminals amount to 70 per cent of the total number of passenger train-miles operated electrically on all American steam railroads. The total passenger car-miles are, however, greater for the Chicago terminals.

4. Freight traffic, based upon information as to number of car-miles exclusive of switching service, is approximately ten times greater in Chicago than on all existing electrified steam railroads in America.

5. Yard freight switching service in the Chicago terminals, on a basis of car-miles, is more than 65 times as great as that on all existing electrified steam railroads in America.

TABLE CCXLV. FOREIGN STEAM RAILROAD ELECTRIFICATIONS. MILEAGE BY CLASSES

Classes	Route Miles	Miles of Main Track	Miles of Other Track	Total Miles of Track
1	2	3	4	5
TRUNK LINES				
North Eastern Railway	29.50	59.00	16.00	75.00
Lancashire & Yorkshire Railway	37.25	74.00	17.00	91.00
Great Western Railway	4.10	8.20	1.40	9.60
Midland Railway	9.25	18.50	0.90	19.40
London, Brighton & South Coast Railway	22.30	53.70	17.00	70.70
Orleans Railway	14.40	52.80	12.20	65.00
Dessau-Bitterfeld Railway	16.12	32.24	15.46	47.70
Loetschberg Railway	45.80	56.80	3.20	60.00
Simplon Railway	13.70	13.70	4.20	17.90
Giovi Railway:				
Ronco to Rivarolo	13.60	27.20	.....	27.20
Rivarolo to Campasso and Rivarolo to Sampierdarena	5.20	.....	27.30	27.30
Freight yards around Genoa and the harbor	......	......	37.90	37.90
Succursale di Giovi	13.60	27.20	......	27.20
Genoa-Savona-Ceva Lines				
Genoa-Savona	24.80	24.80	18.70	43.50
Savona-Ceva	31.00	31.00	8.60	39.60
Mt. Cenis (Bussoleno-Modane) Railway	37.00	57.00	14.60	71.60
Totals	317.62	536.14	194.46	730.60
SECONDARY LINES				
Mersey Railway	4.75	9.50	2.75	12.25
Midi (Cerdagne Line) Railway	35.00	35.00	6.00	41.00
Mittenwald Railway	62.70	62.70	3.40	66.10
Wiesenthal Railway	30.60	43.70	8.65	52.35
Turin-Pinerolo Railway	34.20	34.20	10.60	44.80
Valtellina Railway	90.40	112.40	......	112.40
St. Pölten Railway	56.75	56.75	......	56.75
Vienna-Pressburg Railway	42.90	85.80	......	85.80
Holland Railway	20.40	40.80	6.70	47.50
Rjukan Railway	28.60	28.60	......	28.60
Totals	406.30	509.45	38.10	547.55
Total foreign electrifications under steam railroad conditions	723.92	1,045.59	232.56	1,278.15
Mileage to be electrified in Chicago	565.20	1,475.59	1,963.55	3,439.14
SECONDARY LINES—LIGHT SERVICE, Comparable to American Interurban Railway Service				
Burgdorf-Thun Railway	24.99	24.99	6.01	31.00
Rhätische Railway	38.50	38.50	......	38.50
Fribourg-Morat-Anet Railway	20.00	20.00	......	20.00
Seethal Railway	33.70	33.70	......	33.70
Bernina Railway	37.70	37.70	......	37.70
Milan-Porto Ceresio Railway	45.50	77.50	......	77.50
Thamshavn-Lökken Railway	17.00	17.00	2.40	19.40
Totals	217.39	249.39	8.41	257.80

TABLE CCXLVI. MILEAGE OF AMERICAN AND FOREIGN STEAM RAILROAD ELECTRIFICATIONS

Classes	Route Miles	Miles of Main Track	Miles of Other Track	Total Miles of Track
1	2	3	4	5
Total American	596.98	1,275.14	453.63	1,728.77
Total foreign	941.31	1,294.98	240.97	1,535.95
Total foreign excluding "light service"	723.92	1,045.59	232.56	1,278.15
Grand total, all countries	1,538.29	2,570.12	694.60	3,264.72
Grand total, all countries, excluding "Light Service"	1,320.90	2,320.73	686.19	3,006.92
Mileage to be electrified in Chicago	565.20	1,475.59	1,963.55	3,439.14

The largest and most important service handled in the Chicago terminals is the freight yard switching service. No similar service elsewhere is handled electrically in any considerable volume except on the Giovi Railway of the Italian State Railways and on the New York, New Haven & Hartford Railroad in America. The latter operates, in part electrically and in part by steam locomotives, three freight yards having in the aggregate 72.7 miles of track, requiring about 90,000 electric locomotive-hours per year and handling about 2,500,000 car-miles per year in switching and transfer service. The freight yard traffic of the Chicago terminals aggregates approximately 3,430,000 locomotive-hours per annum and approximately 164,400,000 car-miles per annum in switching and transfer service.

206.04 Equipment and Power Requirements of Existing Electrified Steam Railroads Compared with those of the Chicago Terminals: Facts set forth by a comparison of the electric equipment of existing electrified steam railroads and that of the Chicago terminals present the following conditions:

1. The number of multiple-unit cars, both motors and trailers, required to operate the Chicago service is 66 per cent of the total number of such cars in service on all American electrified steam roads.

2. The number of electric locomotives required for the Chicago service is approximately 4 times the number now in service on all American electrified steam roads and approximately 2.5 times the number now in service on all electrified steam roads in the entire world.

206.05 The Purposes Underlying Electrification: The world's progress in the electrification of steam railroads has resulted from the working out of various purposes. Some steam railroad electrifications which have been widely heralded and have involved large expenditures, have embodied other characteristics possessing greater significance and involving greater expense than the electrical features. In such cases, the purpose sought by electrification has been that of increasing the practicability of a project as a whole. The New York Central and the New York, New Haven & Hartford projects are not alone projects of electrification; primarily they have involved the development of extensive passenger terminal facilities in the midst of a great metropolis. The approach to this terminal is by subway and tunnel, and the details of the improvement have included an enlargement of this approach and a concentration of traffic within it which would have been impracticable under steam operation. The building of the terminal was predicated upon electric operation, but the actual cost of the electrification is but one factor in the cost of an extensive general improvement. Similarly, the electrification project of the Pennsylvania Railroad in New York, while one of the world's great undertakings, is far less significant as a project in electrification than as a great passenger terminal established under peculiar and difficult conditions. Some of the significant factors in the working out of this problem are to be seen in the tunneled approach under the Hudson River, the tunneled entrance beneath and into a great city, the extent of the facilities established for the convenience of passengers and for the expeditious handling of baggage and mail, and the tunneled exit across the city and under the East River to a point on Long Island where space could be obtained in which to build a terminal yard. Electrification came as a necessary detail in the working out of a great plan for an effective and otherwise satisfactory terminal, but electrification alone was not the fundamental purpose of the Pennsylvania Railroad although accepted as a necessary feature of its underground terminal plan.

Obviously, any work of electrification which is undertaken with such varied purposes stands upon quite a different plane from that which must sustain the proposition to electrify the railroad terminals of Chicago, where physical conditions absolutely requiring electrification are lacking. In fact, as appears from this analysis, the physical conditions and the nature of the traffic in Chicago are such as to make electrification extremely difficult. The record of work already accomplished in the electrification of steam railroads, as disclosed by the descriptions of 15 American and 22 foreign projects, shows that the reasons which have stimulated the electrification of steam railroads may be summarized as follows:

1. To meet the requirements of operation under unusual physical conditions, such as those occasioned by an underground terminal, tunnels or heavy grades.

2. To take advantage of available water power in districts in which the cost of coal for steam operation is relatively high.

3. To meet the requirements of an increasing suburban traffic in cases where a frequent and rapid service with comparatively short runs between stops is necessary, or in cases where terminal facilities have proved insufficient for the handling of service by steam operation.

4. To increase the capacity of stub-end terminal stations without physical enlargement, a result which is accomplished by reducing the number and extent of idle movements in the station and through its approach switches.

5. To provide a means of conducting experiments for the purpose of determining the effect of electric operation in stimulating traffic.

6. To meet the competition of electric suburban or interurban railways.

The record of the work already accomplished is significant also in the following particulars:

1. It presents no instance in which a steam railroad occupying surface or elevated lines has been electrified primarily to avoid the pollution of a city's atmosphere.

> 2. Nowhere in the world has a railroad having a city terminal, which from an operating standpoint has been satisfactory, changed its operation from steam to electric.

206.06 Results of Electric Operation under Steam Railroad Conditions: Complete information with reference to the operating results and economics of existing electrifications has not been obtainable in any case. Much has been written regarding the relative economy of electric operation as compared with steam operation but little of value is actually known. Comparisons have been made on a basis of theoretical figures only, or in connection with electric operation on roads which do not present conditions parallel to those which prevail in steam operation. For instance, the Long Island Railroad operates its suburban business electrically and its long distance through traffic by steam. Obviously, a comparison of the operating expenses of these two services does not serve to disclose the operating result of electrification, since the two services are widely different. The suburban passenger service necessarily has more frequent schedules, a larger number of stops and shorter distances between stops than the steam service. The cars provided for the suburban service also are different from those used in the through service.

The operating result which may be expected from the electric operation of the Chicago terminals is evaluated elsewhere in this report (chapter 301).

206.07 Significance of Existing Electrifications Compared with that of the Proposed Electrification of the Chicago Terminals: The art of electrification as disclosed by the descriptions presented in the preceding chapter has developed by small increments, each project being based to some extent upon the success of methods employed in previous undertakings. Methods and essential features have differed, and the process of development has been one which has necessitated a great deal of experimentation on the part of the railroads.

There are today no recognized standards for such important features as the system of traction or the type of locomotive. The art is rapidly developing, however, and it is reasonable to expect practices to become standardized at a future time.

The Committee's plan contemplates, at one stroke, an installation which in many features exceeds in magnitude and importance the combined existing steam railroad electrifications of the world. Of the 15 electric installations in America, 10 are on trunk line steam railroads, while 23 trunk line systems are affected by the Committee's plan. The 10 existing American trunk line electrifications are upon railroads in which there is some duplication of ownership, and for purposes of comparison with the proposed Chicago electrification two of this number may be eliminated since they do not handle heavy trains by electric locomotives.

Of these trunk line railroads, the Pennsylvania Railroad and New York Central & Hudson River Railroad do not handle freight service by electric equipment. The New York, New Haven & Hartford Railroad is the only one of these railroads which handles freight switching service electrically. Of the total of 15 American electrifications, nine were installed because of operation in subways or tunnels, one as an experiment to test out economy in long distance passenger service, two to retain suburban business, one was equipped for initial electric operation because of charter requirements and two for the purpose of utilizing water power instead of coal.

Of the foreign electrifications, all English lines may be classed as suburban. None conducts heavy electric locomotive service and none freight service except in a very minor degree. Practically all electric service is confined to suburban and interurban traffic handled by motor cars. In France, the Orleans Railway confines its electric locomotive operation to passenger trains through a subway entrance into an underground terminal. It also operates electrically a suburban motor car train service on a line connected with this terminal. The Midi electrification is, in its present stage, experimental only. In Germany, no considerable heavy electric main line traction is as yet in operation; the Dessau-Bitterfeld is a short line and has been operated only in experimental service to test out apparatus and methods. The Magdeburg-Leipzig-Halle line, an important extension of which the Dessau-Bitterfeld line will form a part, when completed, will represent the first German trunk line electrification and the Lauban-Kōnigszelt line will represent a second such electrification. Both are predicated upon the production of cheap centralized power either from low grade coal or from hydro-electric plants. While both of these lines will conduct a heavy electric locomotive passenger and freight service, neither of them will conduct a freight switching service comparable with that which exists on the Chicago terminals. In Switzerland, the Loetschberg line and the Simplon Tunnel line were electrified primarily because of tunnel operation; other Swiss electrifications are for light multiple-unit train service only. All Swiss electrifications utilize cheap water power instead of the more expensive coal fuel. In Italy, the Giovi with its branches is the only road which operates heavy electric service.

The secondary lines in foreign countries operate a service which is entirely different from American railroad service, and these electrifications are of interest only in that they illustrate the fact that trains can be operated electrically to advantage on heavy grades.

207. EXISTING ELECTRIC TRACTION SYSTEMS

SYNOPSIS: Steam railroad electrifications already undertaken in America and in foreign countries have been accomplished through the use of several distinct systems of traction. These have differed much in important details. This chapter presents descriptions of the various elements of the different systems. Upon the basis of the facts thus made of record, the applicability of certain systems of electric traction to the Chicago conditions has been established.

207.01 Definition: The term "electric traction system," as generally employed, refers to the entire arrangement under which are assembled and controlled the various factors by means of which power is generated, distributed and used in the propulsion of trains or cars. It embraces the following essential elements:

1. The central source or sources of power at which electric current is generated.
2. The means of distributing the current to subcenters or substations.
3. The means of transforming, regulating or converting the current at the substations.
4. The contact system above or alongside the track to provide the means for delivering the current from the substations to the motive power units.
5. Motive power units which receive electric current from the contact system and use it in motors for propelling the trains.
6. The means of returning the electric current from the motive power units to the substations from which it is distributed.

In electric traction, the power is generated in a central plant; in steam traction, each motive power unit generates and utilizes its own power. Continuity of service in all elements of an electric traction system is essential to successful operation, while with steam locomotive traction, operation is dependent upon individual motive power units.*

Electric traction systems may differ from one another in many important details of design and construction. One of the fundamental points of difference lies in the character of the means employed to convey the current to the locomotives and the motor cars. With regard to this fundamental difference, traction systems may be classified as:

1. Those employing third rail conductors along the tracks (third rail systems).
2. Those employing overhead contact conductors (overhead contact systems).

Another fundamental point of difference lies in the kind of current used. With regard to this feature, electric traction systems may be classified as:

1. Direct current systems.
2. Alternating current systems.

Direct current may be employed at either high or low voltage. Alternating current may be single-phase or three-phase and may also be classified as to frequency and voltage.

The earliest successful application of electricity to traction purposes was made in connection with street railways. The overhead trolley wire was employed for carrying the current to the motive power units. Direct current at about 500 volts was used. The capacity of the small overhead trolley wire for carrying heavy currents was limited, however, and when steam railroads conducting heavy train service electrified their lines the third rail contact system was used to provide the necessary current-carrying capacity. Subsequently the overhead contact system using high voltage single-phase or three-phase alternating current was employed for such traction. More recently, equipment for the use of direct current at relatively high voltage with overhead contact instead of third rail has been developed. Contact voltages which have been successfully employed on existing electric traction systems are as follows:

Third Rail System:
  Direct current — up to 800 volts.
Overhead System:
  Direct current — up to 2,400 volts.
  Single-phase alternating current — up to 15,000 volts.
  Three-phase alternating current — up to 6,600 volts.

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*A special form of electric traction applicable to certain peculiar conditions employs self-contained motive power units in which power is supplied by means of storage batteries or internal combustion engines driving electric generators (chapter 204). Such units, however, are not applicable to the service of the Chicago terminals, and a system of traction employing self-contained electric units is not generally known or referred to as an electric traction system.

Examples of each of these systems may be found on electrified steam railroads in America or in foreign countries. Successful operation has been maintained with them for a sufficient period of time to demonstrate their efficiency and practicability and to establish them as reasonably permanent types.

In a typical third rail system electric energy is transmitted from the power station to the substations as alternating current at a voltage considerably higher than that used on the contact rail. In the substations the transmission voltage is reduced by transformers and the current is converted from alternating to direct current by rotating machines. This direct current is distributed from the substations to the third rail contact system at approximately the voltage for which the motors on the locomotives or motor cars are designed. The motive power units utilize the energy for propelling, for lighting and usually for heating the trains. The track rails ordinarily are employed to complete the electric circuit between the motive power units and the substations.

The typical high voltage direct current overhead system is similar to the third rail system; the current from the source of power is transmitted as alternating current to the substations and the voltage is stepped down to that required for the conversion units. The conversion to direct current is accomplished as in the third rail system by means of rotating machinery, and the current from the substation is fed to the overhead contact system and thence to the locomotives or motor cars. The motors on locomotives or motor cars are not designed for direct current operation at the contact voltage but are grouped in pairs connected permanently in series, an arrangement which reduces the voltage upon each motor to half the total voltage. The track rail is usually employed for the return circuit.

In the typical single-phase alternating current system, the electric power (either single-phase or three-phase) is transmitted from the generating station to the substations as alternating current at high voltage. At the substations single-phase current is delivered, by means of suitable transformers, at the proper voltage to the overhead contact system. The locomotives or motor cars are usually equipped with a transformer by means of which the voltage of the contact is further reduced to a workable and safe value for the motor equipment. As with the direct current systems, the track rail is usually employed for the return circuit.

In the typical three-phase alternating current system, three-phase electric current is transmitted from the generating station to transformer substations, where it is reduced in potential and delivered to the contact system. The transmission and distribution of three-phase current, however, involve the use of three conductors for each circuit, while the transmission and distribution of single-phase current require only two. The contact system for three-phase current consists of two contact wires insulated from each other and placed above the tracks. These, with the return circuit formed by the track rails, complete the three-phase electric circuit between the locomotives or motor cars and the distributing stations. The locomotives or motor cars have two independent current collectors and three-phase motors. When transformers are used on locomotives or motor cars, as is generally the case, their purpose is to reduce the voltage of the contact system to that suitable for the particular motor equipment used.

POWER STATIONS

207.02 Types of Power Stations: In all electric traction systems provision is made for one or more central power stations for the generation of electric energy. Such power stations may be classified as follows:

1. Steam engine generating stations employing some form of combustible fuel (coal, oil or gas) under boilers and steam engines driving electric generators.
2. Combustion engine generating stations using oil or gas by direct combustion in the engine cylinders.
3. Hydro-electric stations in which water power is used to drive water wheels coupled to electric generators.

207.03 Steam Power Stations: The steam power station using coal for fuel is the most common type of central station employed for railroad work. It consists generally of three main sections, as follows:

1. The boiler room containing the boiler equipment, coal supply and coal handling apparatus for the production of steam.

2. The engine room containing steam driven turbines and electric generators which convert the steam power into electric energy.
3. Electric apparatus rooms or galleries containing the regulating devices employed to handle the generating units, and the transforming and protective appliances interposed between the generators and the outgoing wires or cables.

Power station equipment is usually housed in a fire-proof building of substantial construction. The several sections, especially that devoted to boiler equipment, may be subdivided as a means whereby the effect of accidents may be localized. Such power stations are usually located in close proximity to an ample supply of water, which is necessary for condensing the steam from their engines. A view of a representative steam power station for generating electricity is shown by fig. 487.

The prime movers employed in modern steam power plants for electric traction purposes are usually of the steam turbine type. The electric generators are direct connected to the steam turbines, the generator and turbine being mounted on the same bed plate and the two making together a turbo-generator. The generators are commonly three-phase alternating current machines with voltages, in some instances, as high as 13,200. A frequency of 25 cycles per second is standard for generators used for electric traction systems in the United States. In addition to the turbo-generators, the turbine room provides space for auxiliary apparatus, such as engine, turbine or motor driven exciter units for supplying the field current for the generators. Condensers and pumps are also installed in the turbine room, or in rooms under the turbine room. Frequently space is provided in the engine room for sub-station apparatus.

Examples of installations of steam turbines in modern traction power stations are illustrated by figs. 488 and 489.

The control and distribution of the power generated in electric traction power stations necessitate elaborate control and protective apparatus, and when the transmission voltage is higher than that of the generators, step-up transformers are required. This apparatus is generally installed in electric apparatus rooms or galleries of the main building, but sometimes is placed in a separate adjacent building. Oil switches for the generators and transmission lines are installed in compartments located frequently at considerable distances from the switchboard which controls them. The switchboard is equipped with recording and indicating instruments, synchronizing apparatus, rheostat control, and voltage regulators required for the proper operation of the electric generators. The transformers for the transmission lines are commonly arranged in compartments or rooms isolated from the control apparatus. The transformers may be either oil, water or air cooled. They are usually single-phase units grouped to provide the desired phase and voltage transformation for the transmission lines. The outgoing transmission lines are provided with reactance coils, lightning arresters and circuit breakers, which provide protection for the apparatus in power stations from possible damage due to overloads, grounded lines, short circuits

FIG. 487. POWER STATIONS. Steam Power Station, Port Morris, New York City, New York Central & Hudson River Railroad.

FIG. 488. POWER STATIONS. Interior View, Power Station of the Pennsylvania Railroad, New York City. Capacity 32,500 kw. for Traction and 6,000 kw. for Lighting.

and lightning. In the design and construction of a power station, attention is given to the arrangement of the apparatus in the circuit between the generators and the transmission lines, with the object of isolating high voltage equipment from low voltage equipment.

Views of the generating and feeder switchboard, and of the high voltage circuit breakers of a typical power station are shown by figs. 490 and 491.

207.04 Water Power Electric Generating Stations: Few American steam railroad electrification projects are so located as to permit the utilization of water power for generating current. In Europe, however, the availability of water power has been an important factor influencing the installation of electric traction systems (chapter 205). The principal elements of a water power generating station include the water supply delivered into a building which contains the water turbines, the electric generating apparatus, and the switching and control apparatus, as described in connection with steam power stations. The characteristics of the electric generators are similar, as regards voltage and frequency, to those used in steam plants, but the speeds and consequently the sizes of the generators vary greatly for a given capacity, depending upon the character of the water power development. Thus, high head developments utilize high speed turbines and generators as in steam practice, but low head developments employ low speed turbines and the direct connected generators are correspondingly large.

FIG. 489. POWER STATIONS. Interior View, Port Morris Power Station of the New York Central & Hudson River Railroad. Capacity, 20,000 kw.

207.05 Gas Power Generating Stations: Gas engine or internal combustion engine power stations have thus far been but little used for electric traction systems, there being only one instance in which this form of power constitutes the sole source of energy supply for a steam railroad electrification.

The main elements of a gas power plant include the gas supply, the engine room and the electric apparatus room. The fuel may be either a natural gas, a by-product gas obtained from some industrial process or a producer gas. There are few localities favored with a sufficient supply of natural gas and there are practically no instances in which sufficient amounts of by-product gas are available.

The engine room of a gas power station contains gas engines driving electric generators, exciters and engine starting apparatus. The equipment of the electric apparatus room is substantially the same as that used for steam or water power plants.

207.06 Combination Power Stations: Existing power stations in many instances utilize a combination of different kinds of power. For example, a water power station generally has an auxiliary steam power plant used to provide a reserve for low water periods or for heavy peak loads. Frequently two or more separate power plants may furnish power to a traction system. In instances of this kind a steam power plant may be located at one point and a water power plant at another.

TRANSMISSION SYSTEMS

207.07 Purpose of the Transmission System: The purpose of the transmission system is to supply a means of conveying the electric energy from the power station to points at which it is transformed, and in some cases converted, and from which it is distributed to the contact system. Power may be distributed either as alternating current or as direct current, but, owing to the fact that alternating current may be transformed and transmitted at higher voltage than direct current, greater economy is possible with systems in which the power is transmitted as alternating current, and for this reason it is universally used in heavy railroad work.

Conductors for transmission lines are of copper or aluminum wires, the former being more generally employed. These may consist of bare wires or cables supported on poles or overhead structures, of insulated cables placed underground, or of combinations of overhead and underground lines.

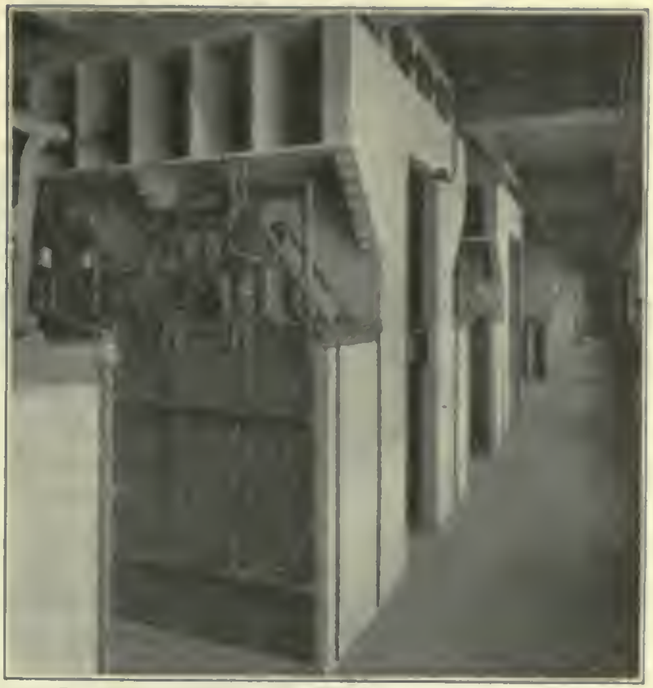


FIG. 491. POWER STATIONS. Circuit Breakers and Compartment, Power Station of the Pennsylvania Railroad at New York City.

FIG. 490. POWER STATIONS. Bench Board in Switching Gallery, Power Station of the Pennsylvania Railroad at New York City.

207.08 Overhead Transmission Lines: When the electric current is transmitted by overhead conductors, the circuit usually consists of two or three wires separated at sufficient distance from each other to prevent interference or short circuits. These conductors are carried on insulators attached to the supports. The size of the conductors is determined by the electrical conductivity requirements and by the load due to the weight of the conductor and to wind, ice and temperature stresses. The transmission line insulators are of various designs. Porcelain, which has high mechanical and electrical strength, is generally used. The supports may be wooden poles, reinforced concrete poles, steel poles, or steel towers or bridges. These structures are designed to support the various circuits of the transmission lines at certain minimum distances above the ground. Wooden poles, when used for supports, are normally spaced at intervals of about 100 feet. Steel poles or steel towers are frequently spaced at intervals of 600 feet and, under special conditions, very heavy construction has been used for spans as great as 3,000 feet. In many transmission lines, a ground wire is carried several feet above the transmission wire as a means of protection against lightning. This wire usually is of steel and is grounded at frequent intervals. Existing overhead transmission lines for electric traction systems carry current at voltages ranging from 11,000 to 100,000.

207.09 Underground Transmission Systems: Underground transmission of electric current is accomplished by means of lead covered insulated cables installed in underground ducts. The several conductors of a circuit are usually combined in one cable. They are insulated from each other and from the lead sheath. The underground ducts or conduits in which the cables are carried may be of fiber, concrete, hollow brick or tile, iron pipe or other materials. The ducts are installed in sections a few feet below the surface of the ground in such manner as to provide a smooth interior surface which permits the cables to be drawn in or removed as desired. Splicing chambers for connecting the ends of the cable lengths are located in the conduit line at intervals of about 400 feet. Underground transmission cables are seldom used for voltages higher than 11,000, although experimental lines of considerably higher voltages have been installed in Europe on railroad electrifications.

207.10 Relation of Transmission Lines to Electric Traction Systems: Traction systems employing third rail contact, high voltage direct current overhead contact or three-phase alternating current overhead contact, generally use three-phase alternating current transmission lines requiring three conductors for each circuit. Single-phase alternating current overhead contact systems are usually equipped with single-phase alternating current transmission lines requiring two conductors for each circuit. A few installations are in existence in which the transmission line has been omitted, the current being delivered to the contact system by means of a distributing system radiating from the power station. Such installations are confined to the single-phase and the three-phase alternating current systems.

In traction systems employing overhead contact the transmission line commonly follows as far as practicable the same route as the electrified tracks, and extensions of the supports provided for the overhead contact system are used to support the transmission line. Traction systems employing third rail contact require either a separate pole line or an underground conduit for the high tension transmission wires. Combinations of overhead and underground transmission lines are frequently used for installations in which part of the line passes through tunnels or under bodies of water. In such instances, lightning protection for cables is installed at the point of juncture between the overhead and underground lines.

The transmission line is the weakest link in the chain of elements of the power supply. Its service may be interrupted by storms, lightning or other influences. In order to guard against interruptions, more than one transmission circuit is usually provided. The duplicate circuits often follow different routes.

Views of typical transmission lines are shown by figs. 492 to 494, inclusive.

SUBSTATIONS

207.11 Functions of the Substation: The power substation performs the functions of transforming, converting or regulating the primary current delivered by the transmission line in accordance with the particular needs of the

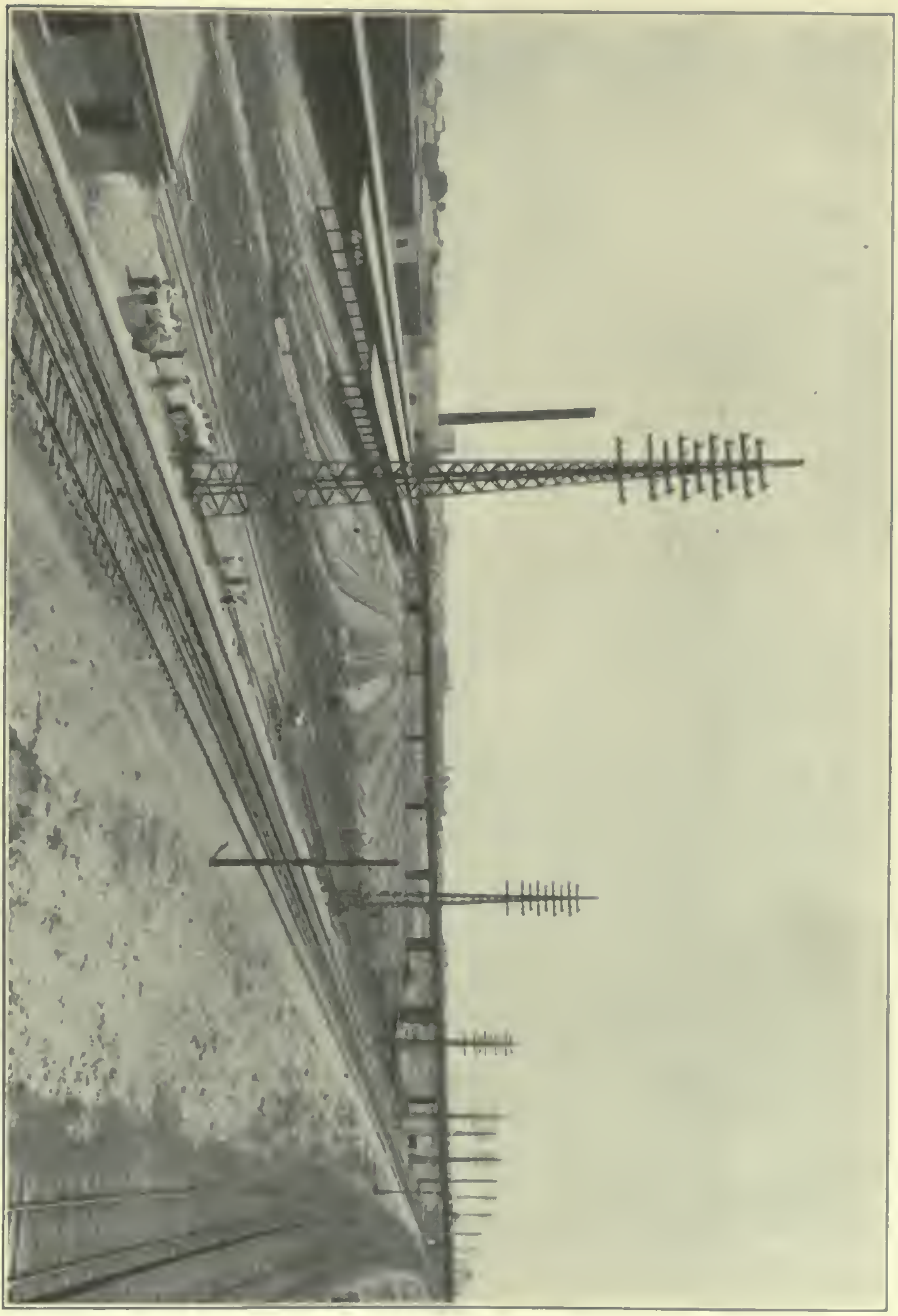


FIG. 492. 11,000-VOLT, THREE-PHASE TRANSMISSION LINE, LONG ISLAND RAILROAD, NEAR NEW YORK CITY

The Line is Supported by Structural Steel Poles Set in Concrete Foundations.

FIG. 493. 11,000-VOLT, THREE-PHASE TRANSMISSION LINE, NEW YORK CENTRAL & HUDSON RIVER RAILROAD, NEAR NEW YORK CITY

The Supports are of Structural Steel Set in Concrete.

current supply for the contact system. Substations are located at such intervals along the line of road as are necessary to provide for the economical distribution of current and to meet the requirements for feeding the contact system.

207.12 Substations for Third Rail Systems: The equipment of a typical substation for a direct current third rail system of traction includes the following:

1. Transformers which step down the alternating current transmission voltage to that required for the converting apparatus.
2. The converting apparatus which changes the alternating current into direct current.
3. The switching apparatus for regulating, controlling and protecting the incoming transmission circuits, the circuits of the substation apparatus and the circuits through which the direct current is distributed to the contact system.

The high potential current is introduced into the transformers through oil circuit breakers and reactance coils. The transformers are usually single-phase units, a set of two or three for each conversion unit being necessary to step down three-phase current from the transmission line to the required voltage for the conversion units. These transformers may be oil, air or water cooled, depending upon the voltage and upon local conditions. The converting machine may be either a rotary converter or a motor-generator set. A rotary converter consists of a synchronous alternating current motor and a direct current

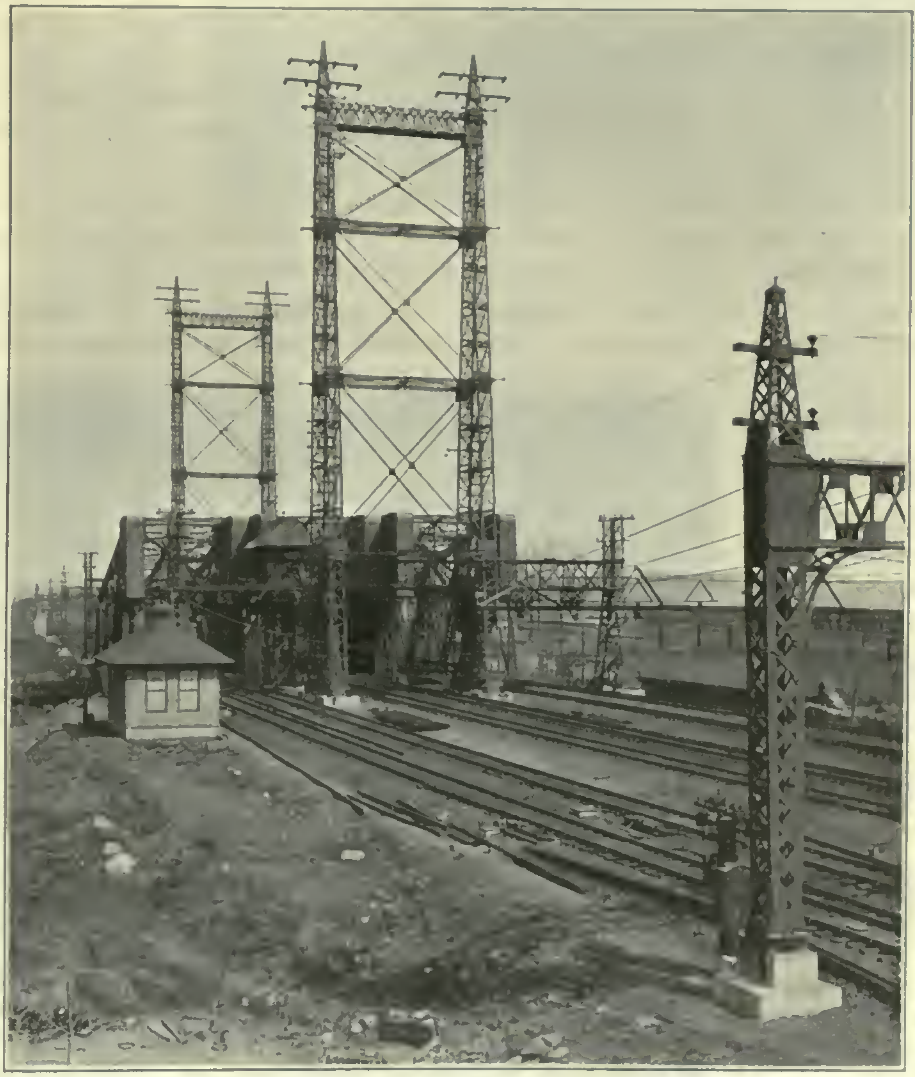


FIG. 494. TRANSMISSION LINES. Supporting Structures for Transmission Line at a River Crossing, New York, New Haven & Hartford Railroad.

FIG. 495. SUBSTATIONS. Exterior View of Substation of the New York Central & Hudson River Railroad. The Building is Constructed of Brick and the Transmission and Feeder Supports are of Structural Steel.

generator, combined in a single unit with but one armature and one field frame. A motor-generator set consists of an alternating current synchronous or induction motor direct connected to a direct current generator. The rotary converter, which is a more economical and efficient piece of apparatus, is generally used. The direct current from the converters is fed to the third rail contact through feeders. The feeder circuits are equipped with circuit breakers and instruments for indicating the load. The substation apparatus is housed in fire-proof buildings, and lightning arresters are provided for the protection of the apparatus. Because of the presence of moving machinery, attendants are required.

Substation loads are subject to wide fluctuations. In some installations the load is regulated by means of storage batteries in the direct current circuit. These batteries are connected across the bus-bars of the distributing circuit. With the aid of boosters, these batteries feed current to the line when the substation apparatus is under heavy load and are charged from the bus-bars during periods of light load. The capacity of the batteries is usually sufficient to carry the station load for short periods and thereby to provide protection against a break-down or shut-down of the apparatus. Special ventilated rooms isolated from the substation apparatus room are provided for the batteries.

The number and location of direct current substations depend upon the magnitude and character of the electric load and upon local conditions. The substations are as few and are spaced at as wide intervals as is consistent with good voltage regulation at the trains under maximum load conditions.

Exterior and interior views of a substation for a third rail electric traction system are presented as figs. 495 and 496.

207.13 Substations for High Tension Direct Current Overhead Systems: Substations for

FIG. 496. SUBSTATIONS. Interior View of Substation of the New York Central & Hudson River Railroad.

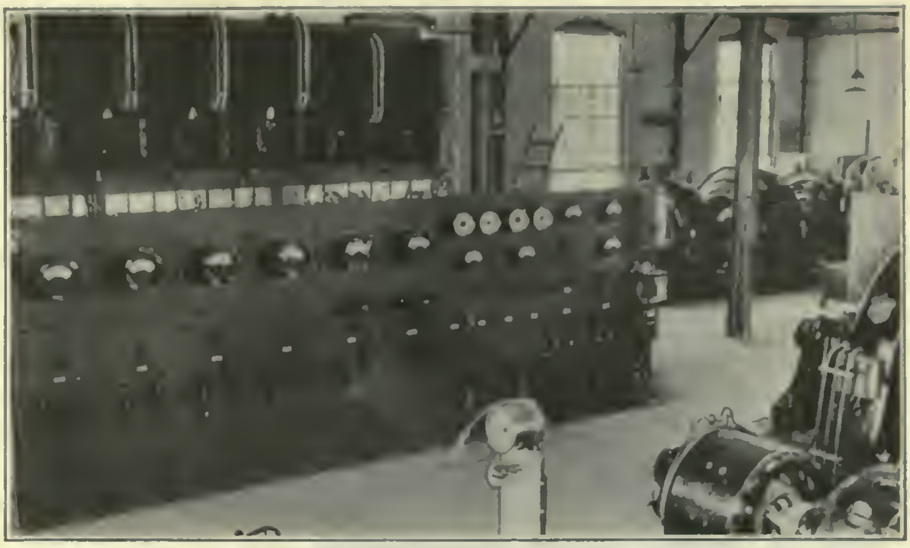


FIG. 498. SUBSTATIONS. 2,400-Volt Direct Current Substation, Butte, Anaconda & Pacific Railway. Motor-Generators are Used for Conversion Units.

high tension direct current overhead contact systems are similar to those used for third rail installations, the principal difference being in the fact that the apparatus is arranged to provide high voltage current instead of low voltage current for the contact at the trains. The high tension alternating current of the transmission lines is transformed to the voltage required for the conversion units which deliver the converted current to the contact wires through the feeder switching apparatus of the station. The transformers are protected on the primary side by oil circuit breakers and by lightning arresters. The current is converted by means of rotary converters or motor-generators. If rotary converters are used, two machines of the interpole type are provided. The two machines are mounted on the same bed plate and the armatures have a common shaft. They are connected in series through their direct current terminals. In installations in which the current is converted by means of motor-generators, one alternating current motor is mounted with two direct current interpole generators on a single base, the three machines having a common shaft. The terminals of the direct current generators are connected in series. The series connection of the direct current apparatus is necessary because of the fact that direct current commutating apparatus has not been constructed to operate satisfactorily at voltages higher than 1,500. Installations using 1,200 volts on the contact system are usually provided with sets of two 600-volt rotary converters connected in series and insulated for 1,200 volts, or with motor-generator sets having two direct current 600-volt generators in series and insulated for 1,200 volts. Some installations, however, use rotary converters and motor-generators wound directly for 1,200 volts. Installations using direct current at 2,400 volts on the contact system have similar combinations of apparatus with two direct current machines in series, each

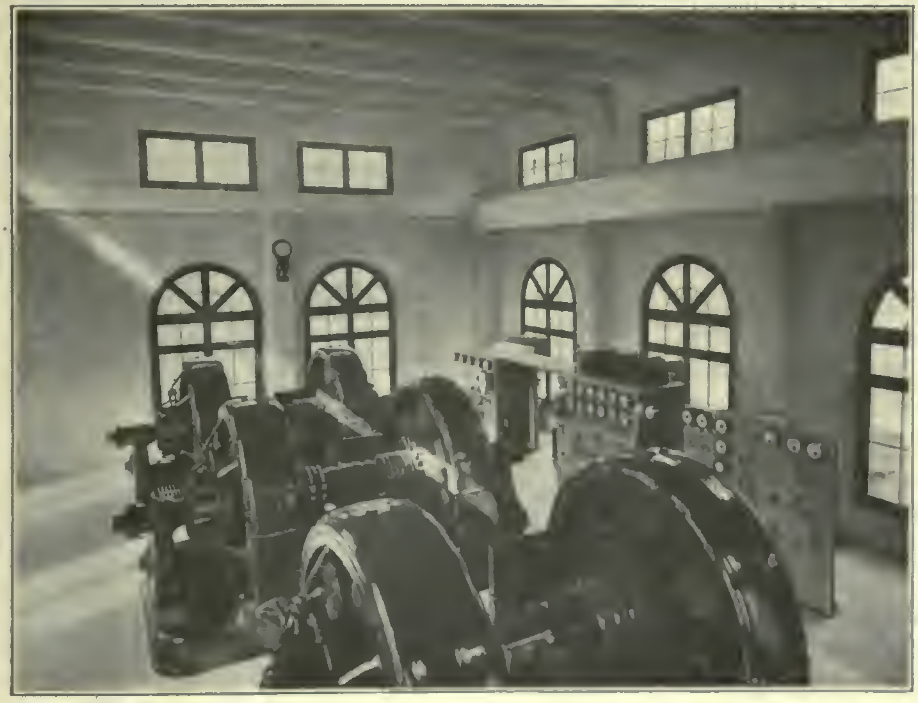


FIG. 497. SUBSTATIONS. 1,200-Volt Direct Current Substation, Southern Pacific Railroad, Berkeley, Cal.

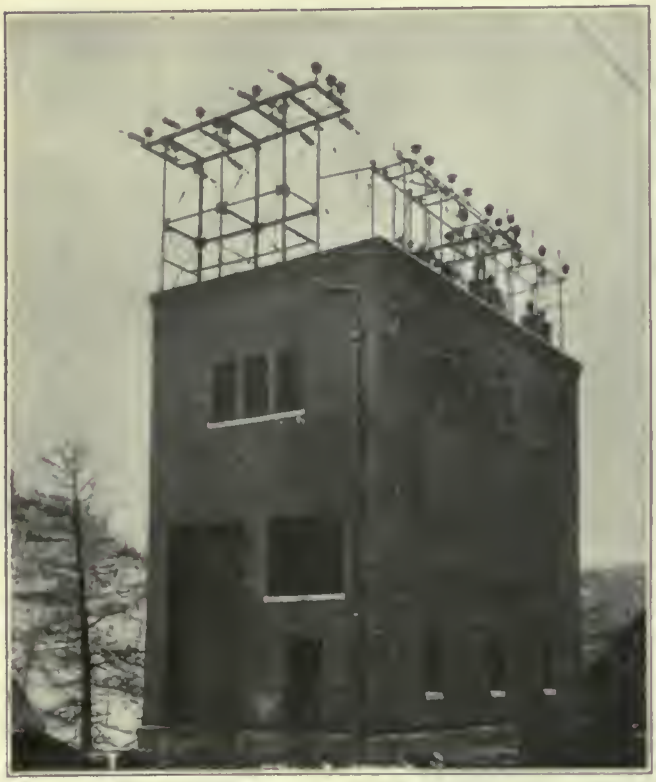


FIG. 499. SUBSTATIONS. 11,000-Volt Single-Phase Substation of the Norfolk & Western Railway.

wound for 1,200 volts and insulated for 2,400 volts. The current is distributed from the substation through feeders equipped with air break circuit breakers and load indicating instruments. As is the case in substations for third rail systems, attendants are required.

Interior views of substations for 1,200-volt and for 2,400-volt direct current overhead contact systems are presented as figs. 497 and 498.

Some experimental work has recently been conducted with a form of mercury arc rectifier for converting large amounts of power from alternating current to high voltage direct current. The satisfactory development of this apparatus will make possible the operation of a substation for transforming and converting current without rotating machinery. The labor cost of operating a substation could, in such case, be reduced and a contact voltage higher than is at present possible with rotating apparatus could be obtained.

207.14 Substations for Single-Phase Overhead Contact Systems: Substations for single-phase traction systems are much simpler than those required for direct current systems. Rotating apparatus is not necessary. It is required only that the high potential transmission current be stepped down to the contact voltage by transformers. Protective devices, such as reactances, lightning arresters and oil circuit breakers, are installed both in the transmission circuit and in the distribution circuit. The single-phase substation does not require the presence of regular attendants although frequent inspections are necessary. The circuit breakers are arranged for control from signal towers or stations sometimes located at considerable distances from the substation. In early installations the apparatus of the single-phase substations was housed in small buildings. In some recent installations outdoor, or unhoused, substation apparatus has been successfully used.

Theoretically it is possible to obtain economical distribution of current in single-phase systems by spacing the substations at considerable distances. Recent installations, however, provide substations at more frequent intervals than would be required from consideration solely of voltage regulation and economy, in order that inductive interferences in adjacent telegraph and telephone lines may be so far reduced as not to be objectionable.

A view of a typical substation installation of the housed type for a single-phase electrification is presented as fig. 499, and a view of an outdoor type is presented as fig. 500.

207.15 Substations for Three-Phase Alternating Current Systems: A substation for traction

FIG. 500. SUBSTATIONS. 11,000-Volt, Single-Phase, Outdoor Substation of the New York, New Haven & Hartford Railroad.

systems using three-phase alternating current on the contact is similar in many respects to the single-phase substation described in the preceding section. The apparatus required, however, is slightly more elaborate. The limiting voltage for the contact is generally lower in three-phase installations than in single-phase installations. Three-phase transformers, or combinations of two or three single-phase transformers connected for three-phase current transformation, are used. The transmission and distributing lines are protected by means of automatic circuit breakers and lightning arresters. Existing installations provide small buildings for housing the switching apparatus and self-cooling transformers. The presence of attendants is not required in the operation, although frequent inspection is necessary.

CONTACT SYSTEMS

207.16 The Function of the Contact System: The "contact" conductor is the link in an electric traction system by means of which the power is delivered to the locomotives or motor cars. In all electric traction systems the contact consists of stationary conductors located alongside or above the track to be served. The conductor must be insulated for electric purposes, and must be isolated and protected to insure safety and continuity of operation. Furthermore, it must be located so as to provide a minimum interference with existing structures or rolling equipment. The current is taken directly from the contact conductor or conductors by means of a rolling or sliding device attached to the locomotive or motor car. The contact equipment requires careful design and construction, and constant attention in maintenance in order that it may satisfy the physical and traffic conditions incident to normal operation. Contact conductors may be classified as "third rail" and "overhead."

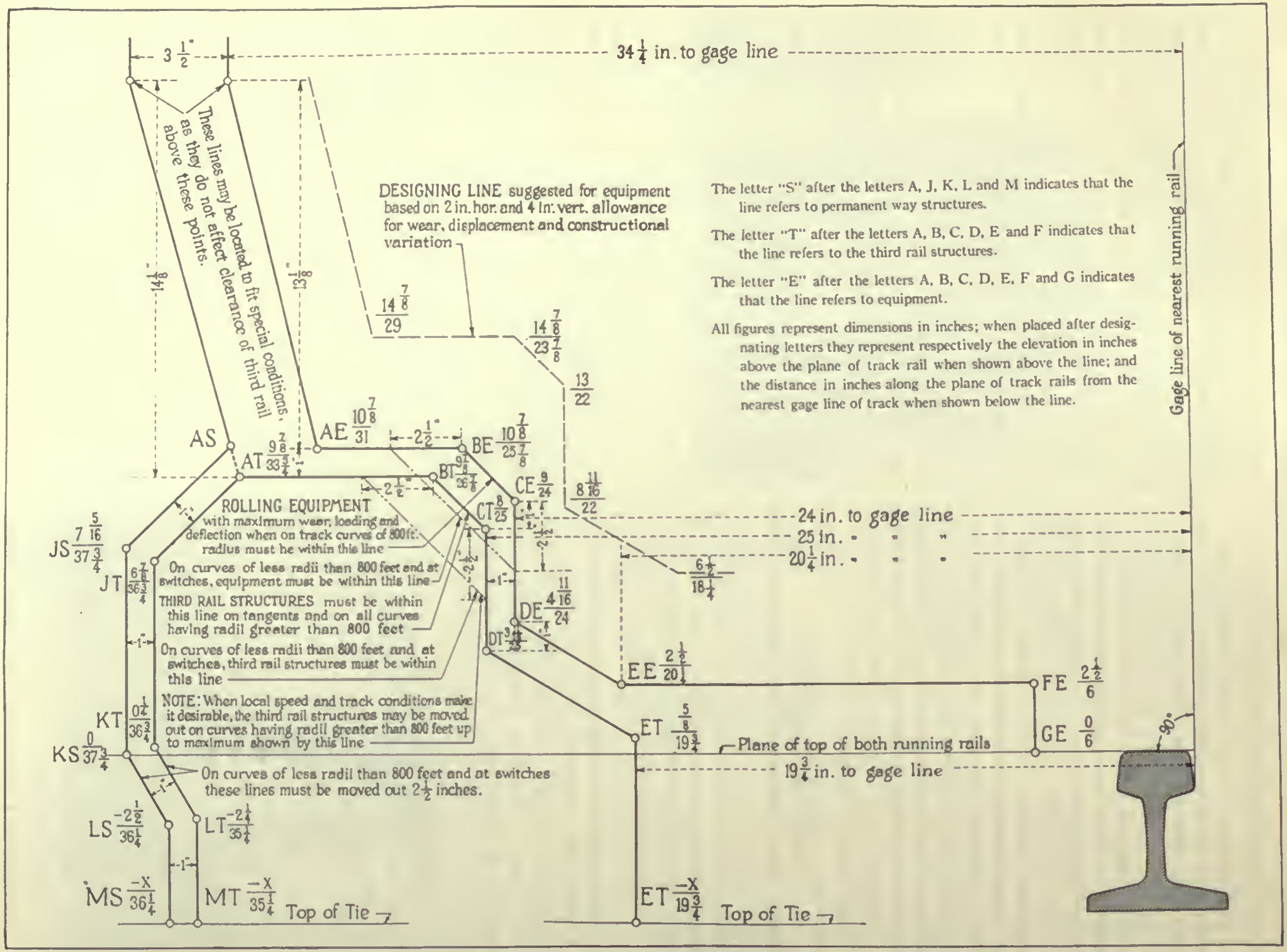
207.17 Third Rail Contact Systems: A third rail contact system consists of a conductor placed alongside the track, supported at a fixed distance from the gage line and above the level of the track rail. The location of the third rail, as standardized by the American Railway Association, is shown in the diagram presented as fig. 501. This location has been established to provide space for insulation, to prevent interference with existing structures and rolling equipment, and to permit of safe and satisfactory operation of the locomotives or motor cars.

The third rail is supported by means of insulators constructed of such materials as are suitable for the voltage employed on the rail. The third rail conductor is usually provided with some form of guard or covering to serve as a protection against accidental contact of employes or others. The conductor rail is of steel, generally of a composition having a lower electrical resistance than the steel used in ordinary track rails. Various third rail sections, with weights ranging from 25 to 150 pounds per yard, are used. The standard rail lengths are 30 and 33 feet. The rails are joined by means of light fish-plates and, to insure electrical continuity, are bonded with copper bonds. Two types of contact rail, the over running and the under running, are in general use.

The over running rail is supported on insulators spaced at intervals of about ten feet. These supporting insulators rest upon extra length track ties inserted in the track at proper intervals. In third rail operation with over running rail, the locomotives or motor cars are equipped with contact shoes which slide along the top of the conductor rail. Protection is provided by means of wooden planking supported several inches above the rail, either on wooden blocks clamped to the third rail or on iron brackets mounted beside the insulator on the extended tie. Occasionally, to meet local conditions, protection is also provided on the outer side of the contact rail.

A drawing showing the position of the third rail with reference to the track rail, the third rail section, and the protection provided in a typical installation of the over running third rail contact system, is presented as fig. 502.

The under running third rail contact differs from the over running third rail contact in that the collecting device, attached to the locomotives or motor cars, makes contact on the under side of the rail instead of on the top. The under running contact rail is supported at intervals of about 10 feet by brackets mounted on extra length ties placed in the railroad track at proper intervals. The supporting brackets are usually of cast iron and are designed to clamp the third rail in such manner as to present a free running surface on the under side of the rail for the contact of the



The letter "S" after the letters A, J, K, L and M indicates that the line refers to permanent way structures.

The letter "T" after the letters A, B, C, D, E and F indicates that the line refers to the third rail structures.

The letter "E" after the letters A, B, C, D, E, F and G indicates that the line refers to equipment.

All figures represent dimensions in inches; when placed after designating letters they represent respectively the elevation in inches above the plane of track rail when shown above the line; and the distance in inches along the plane of track rails from the nearest gage line of track when shown below the line.

FIG. 501. AMERICAN RAILWAY ASSOCIATION'S STANDARD LOCATION FOR THIRD RAIL

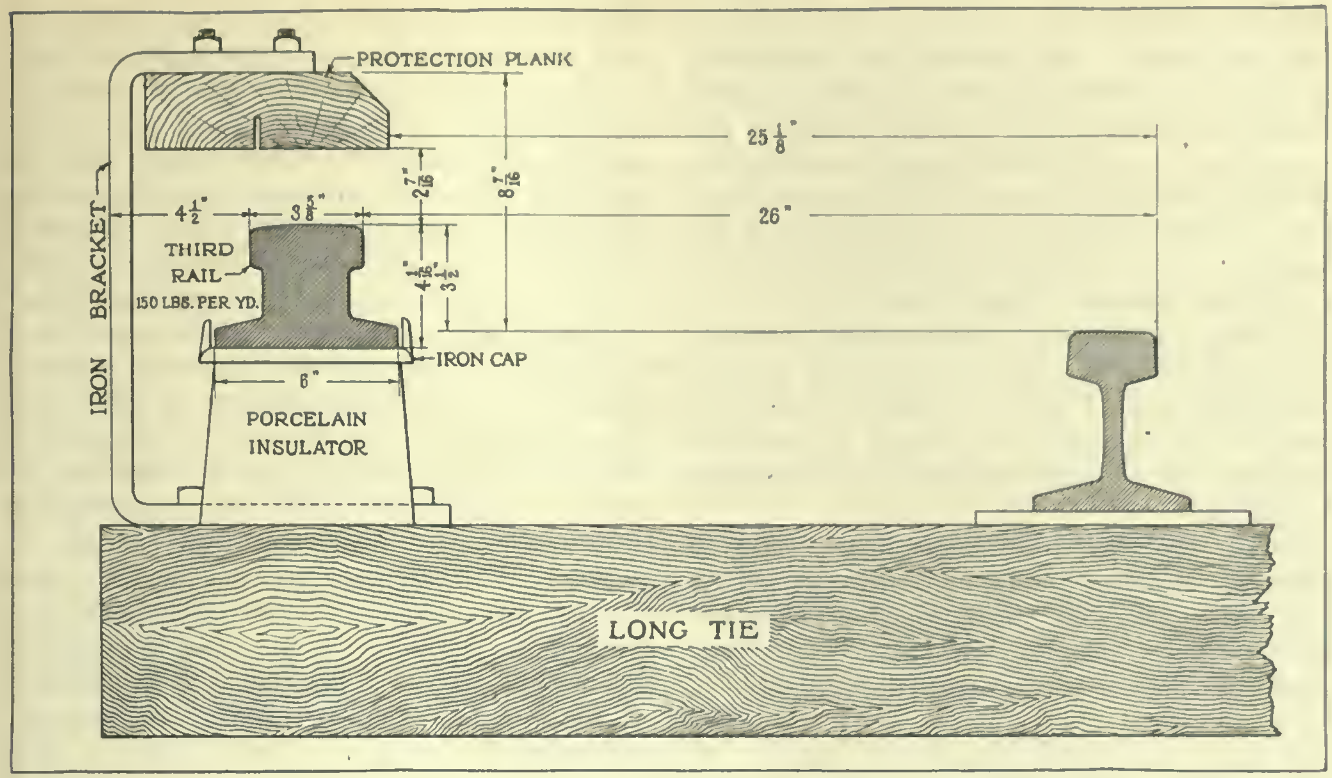


FIG. 502. OVER RUNNING THIRD RAIL INSTALLATION. POSITION OF THIRD RAIL WITH REFERENCE TO TRACK RAIL, THIRD RAIL SECTION, AND PROTECTION PROVIDED

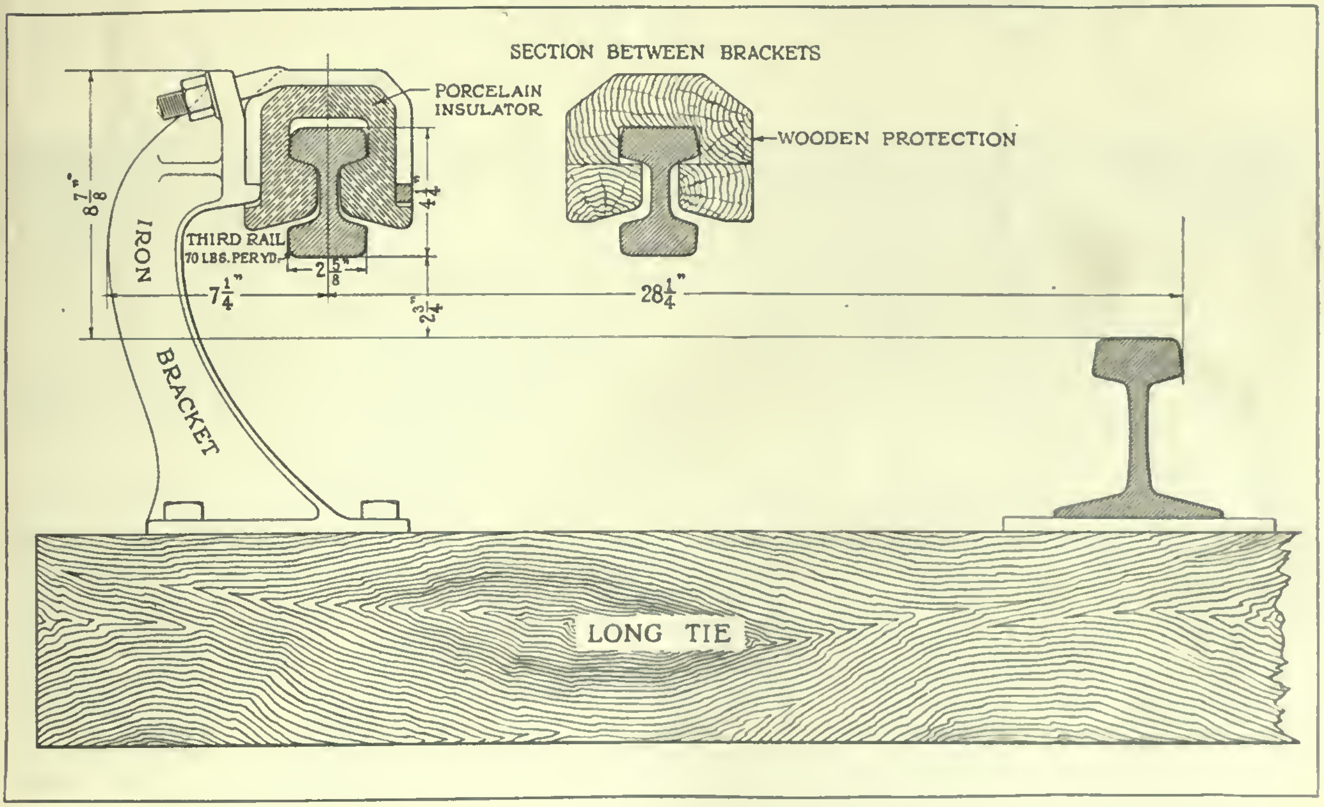


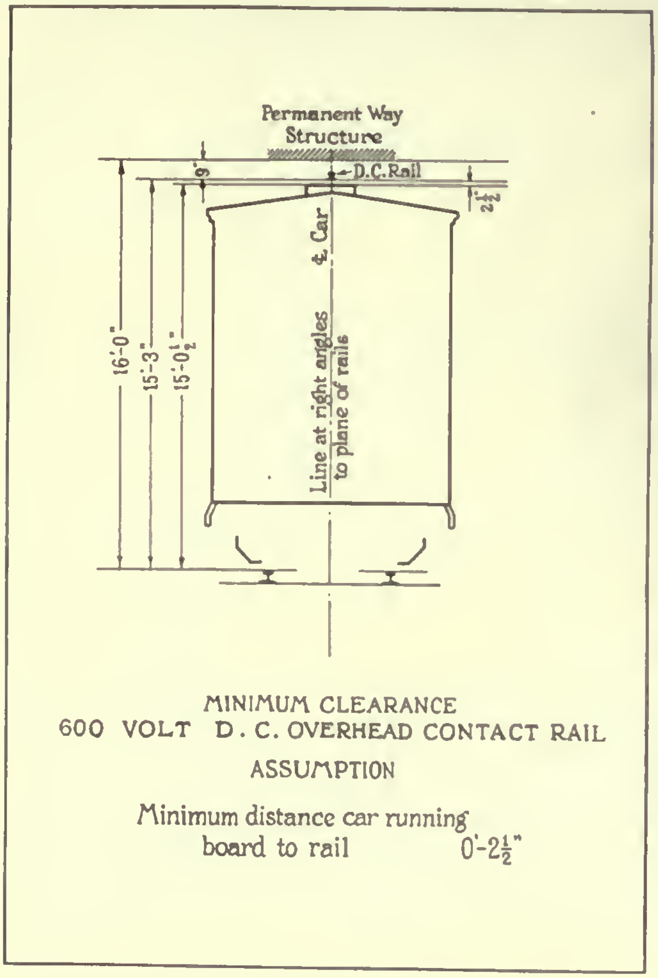
FIG. 503. UNDER RUNNING THIRD RAIL INSTALLATION. POSITION OF THIRD RAIL WITH REFERENCE TO TRACK RAIL, THIRD RAIL SECTION, SUPPORTING BRACKET AND INSULATOR

collector shoe of the locomotive or motor car. The third rail is insulated from the supporting bracket by means of specially designed insulators inserted between the rail and the bracket. The protection for the under running contact rail generally consists of wood or of a fiber compound and is made in sections. The protection is designed to cover all surfaces of the contact rail except the bottom or contact surface.

A drawing showing, in cross-section, the relative positions of the third rail and track rail, the supporting bracket and the insulator, which are employed in a typical installation of the under running type of third rail contact, is presented as fig. 503.

In all third rail installations, it is sought to provide continuous contact for the locomotives and motor cars by having the third rail alongside the track at all points. Gaps are necessary, however, at many points to accommodate various track conditions, such as railroad crossings, crossovers and slip switches, and to allow for road and street grade crossings. The locomotives and motor cars are equipped with contact shoes at both ends, and where the gaps are short no other means are necessary to provide contact, since the distance between the shoes is sufficient to span the gap. Gaps of even greater length may often be crossed by allowing the train to coast over the distance. Where physical conditions make it necessary to provide long gaps in the third rail, other arrangements are necessary to supply the contact. This is accomplished by installing an overhead contact rail carried by, and insulated from, steel supporting structures. Contact is made with this overhead rail by means of a shoe mounted on top of the locomotive or motor car. A minimum clearance for the 600-volt overhead contact rail has been adopted as recommended practice by the American Railway Association, as follows:

	FEET	INCHES
Distance between face of rail and structure	0	9.0
Distance between rolling stock and contact rail	0	2.5
Total clearance above cars	0	11.5
Height of car	15	0.5
Height of permanent way structure	16	0.0



MINIMUM CLEARANCE
600 VOLT D. C. OVERHEAD CONTACT RAIL

ASSUMPTION

Minimum distance car running board to rail 0'-2½"

FIG. 504. AMERICAN RAILWAY ASSOCIATION'S RECOMMENDED PRACTICE FOR LIMITING CLEARANCES FOR OVERHEAD CONDUCTOR RAILS

A drawing showing this arrangement is presented as fig. 504.

The electrical continuity of the third rail circuit at gaps is maintained by installing copper jumpers underground between the ends of rails. These jumpers consist of insulated cables installed in conduits of iron pipe or other duct material. Electrical connection between the third rail and the overhead contact rail is made by means of insulated copper cables.

The third rail conductor is sometimes reinforced electrically by a system of feeders direct from the substation. Such feeders are employed when the conductivity of the maximum desirable size of rail is not sufficient to maintain the minimum voltage required with the economical substation spacing. The feeders and third rail conductors are arranged in circuits through the agency of switching stations located at intervals along the tracks. At these switching stations circuit breakers, either automatic or manual, are provided so that tracks may be sectionalized in case of short circuits or other faults.

Third rail construction for yard tracks is similar to that employed for main tracks except that the contact rail is usually lighter. Because of the number of switches and crossovers which occur in yards, it is frequently necessary to provide a considerable extent of overhead contact construction.

Various voltages are used on third rail conductors, the most common in America being 600 volts. Some installations in the United States, however, use direct current at 1,200 volts on third rail contact. An interurban line is now under construction on which it is proposed to use a third rail contact system with direct current at 2,400 volts. In France, direct current at 800 volts is successfully used with third rail contact. Thus far, third rail contact systems for more than 800 volts have not been used for electric operation under steam railroad conditions.

Views of existing track construction on which the third rail contact system is employed are shown by figs. 505 to 512, inclusive.

207.18 Overhead Contact Systems: Overhead contact for heavy electric traction is a development of the overhead trolley used by street and interurban railways. The use of high voltage current has made necessary the design and construction of a contact which can be satisfactorily insulated, which can be placed in a position calculated to offer the least interference

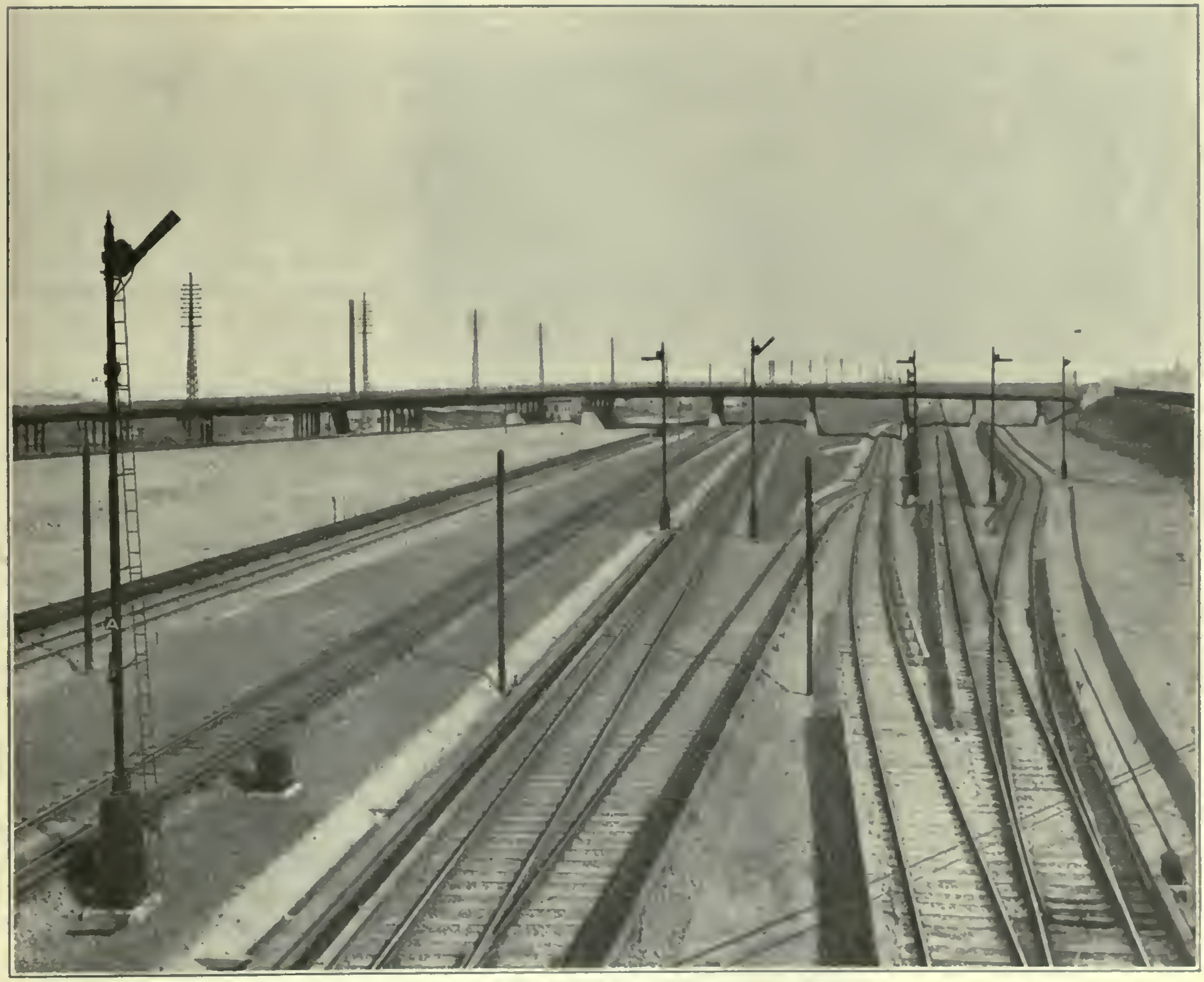


FIG. 505. THIRD RAIL CONTACT SYSTEMS. Main Track Construction, 600-Volt Over Running Third Rail Installation, Pennsylvania Railroad, New York City.

with rolling equipment and fixed structures, and which does not present the possibility of accidental contact by persons. The overhead contact structure must be of such mechanical strength that failure is not more likely than with bridges or other permanent structures. In many overhead contact installations, steel structures, spaced normally at intervals of 300 feet, support the overhead contact wires through the agency of various types of catenary construction which provides the strength and security desirable in the wire structure, and the uniformity in the support of the contact wire necessary to satisfactory results with high speed operation. The height of the contact wire above the tracks has varied in the different installations, standards having only recently been established. The practice recommended by the American Railway Association is as follows:*

CASE I — CLEARANCE REQUIRED FOR TRAINMAN WITH LANTERN

	FEET	INCHES
Distance between wire and structure	0	10.0
Reach of 6-foot trainman	7	8.0
Lantern	1	0.0
Clearance	0	5.5
Total clearance above car	9	11.5
Height of car	15	0.5
Height of permanent way structure	25	0.0

To meet this condition of maximum clearance requirement, where men give signals from the tops of cars, a distance of 9 feet, 11.5 inches, must be allowed from the car to the overhead structure, or a clearance of 25 feet between the top of track rails and permanent way structures such as bridges and viaducts over the track.

CASE 2 — CLEARANCE REQUIRED FOR TRAINMAN WITHOUT LANTERN

	FEET	INCHES
Distance between wire and structure	0	10.0
Reach of 6-foot trainman	7	8.0
Clearance	0	5.5
Total clearance above car	8	11.5
Height of car	15	0.5
Height of permanent way structure	24	0.0

The above case is only permissible where men pass over or ride on cars solely for the purpose of setting brakes, and are prohibited from giving signals from the tops of cars, and to meet this condition, a distance of 8 feet, 11.5 inches, must be allowed from the car to the overhead structure, or a structure clearance of 24 feet.

CASE 3 — NORMAL MINIMUM CLEARANCE WITHOUT TRAINMEN ON CARS

	FEET	INCHES
Distance between wire and structure	0	10.0
Desirable clearance between rolling stock and wire	2	1.5
Total clearance above car	2	11.5
Height of car	15	0.5
Height of permanent way structure	18	0.0

The above case shows 2 feet, 11.5 inches, as the minimum desirable clearance for normal construction, where men are prohibited from riding on the tops of cars.

CASE 4 — SPECIAL MINIMUM CLEARANCE REQUIREMENTS

	FEET	INCHES
Distance between wire and structure	0	10.0
Distance between rolling stock and wire	0	11.5
Total clearance above car	1	9.5
Height of car	15	0.5
Height of permanent way structure	16	10.0

This case is given as representing the minimum clearance which should be used where joint steam and electric operation is involved, and requires a distance of 1 foot, 9.5 inches, from car to overhead structure, and a structure clearance of 16 feet, 10 inches, from the rail. If the railroad is operated by electric power only and steam locomotives are excluded, the above clearances may be somewhat reduced, allowing the electrical conductor to be installed under structures having a height of 16 feet, 6 inches, above top of rail.

The diagrams presented as fig. 513 show these clearance dimensions graphically.

In individual installations, special features of construction are employed to meet the peculiar needs of the system used. The overhead contact for high voltage single-phase current operation usually consists of supports made of structural steel and of catenary wire construction. Catenary construction involves the use of steel messenger cables freely suspended in spans, with a convenient sag between supports located at fixed intervals. The messenger cables support the contact wire or wires by means of vertical hangers of varying lengths. These hangers are spaced at intervals of from 10 to 15 feet and are

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* Report of the American Railway Association Committee on Electric Working, April 21, 1913.

FIG. 506. THIRD RAIL CONTACT SYSTEMS. Main Track Construction, 600 - Volt Under Running Third Rail Installation, New York Central & Hudson River Railroad, New York City.

FIG. 507. THIRD RAIL CONTACT SYSTEMS. Construction at Switches, 600-Volt Over Running Third Rail Installation, Pennsylvania Railroad, New York City.

FIG. 508. THIRD RAIL CONTACT SYSTEMS. Construction at Switches, 600-Volt Under Running Third Rail Installation, New York Central & Hudson River Railroad, New York City.

FIG. 509. THIRD RAIL CONTACT SYSTEMS. 600-Volt Over Running Third Rail Construction, Sunnyside Yard, Pennsylvania Railroad, Long Island City, N. Y.

adjusted to support the trolley wire at a uniform height above the track. The span of the catenary messengers varies from about 150 to 300 feet on straight track, this distance being reduced on curves to provide for proper suspension of the contact wire. Designers of overhead catenary systems have endeavored to obtain a flexible construction which will support the contact wire without appreciable sag, a condition which is essential to the collection of current at high speeds.

There are three general types of catenary construction, the single, double and compound. The single catenary involves the use of a single messenger cable attached to insulators on the supporting structures, and of hangers, dependent from the messenger cable, which support the trolley wire in proper position above the track. The double catenary has two catenary messenger cables supporting the trolley wire, these messengers being supported a few feet apart and at the same elevation. The trolley wire is suspended below the messenger cables at the lower apex of an equilateral triangle of which a line connecting the two messengers forms the opposite side. Compound catenary construction involves the use of two messenger wires, one being carried on the main supports without insulators and the other being supported by intermediate insulators dependent from the first messenger. The trolley wire is supported by hangers dependent from the second messenger, as in the case of the single catenary construction.

The support of the contact wire has received careful attention. It has been found that when this wire is suspended directly from the messenger wire, the points of support present hard spots in an otherwise flexible conductor. These hard spots cause the collecting device, when moving at high speed, to leave the wire, with the result that arcing is produced. To obviate this trouble, a second wire is hung a few inches below the trolley wire and supported by clips at midpoints between messenger hangers. This contact wire is found to present a flexible surface for the collecting devices. On some installations the catenary messenger supports a copper secondary from which a steel contact wire is suspended; in other and more recent installations the contact wire is of copper alloy suspended from a steel secondary.

The insulators for the single-phase overhead contact, which support directly the catenary construction, are subjected to heavy mechanical and electrical strains. Porcelain is generally used for insulators when the mechanical loads either of compression or tension are high; impregnated wood is sometimes used in tension. On installations where both steam and electric services are operated the insulators must be of particularly high electrical strength, since the deposits from locomotive gases tend materially to reduce the insulating capacity. In single or double catenary construction the messenger cables are usually supported by means of suspension or pin type

FIG. 510. OVERHEAD THIRD RAIL CONSTRUCTION, TERMINAL AREA, PENNSYLVANIA RAILROAD PASSENGER STATION, NEW YORK CITY

This Type of Construction is Employed when Conditions do not Permit the Installation of Third Rail alongside the Track.

FIG. 511. YARD TRACK CONSTRUCTION, 600-VOLT OVER RUNNING THIRD RAIL
Position of Passenger Coaches with Reference to Third Rail, Sunnyside Yard, Pennsylvania Railroad, Long Island City, N. Y.

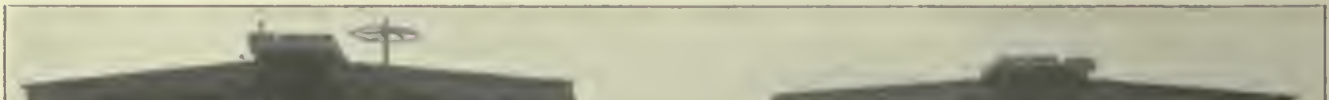
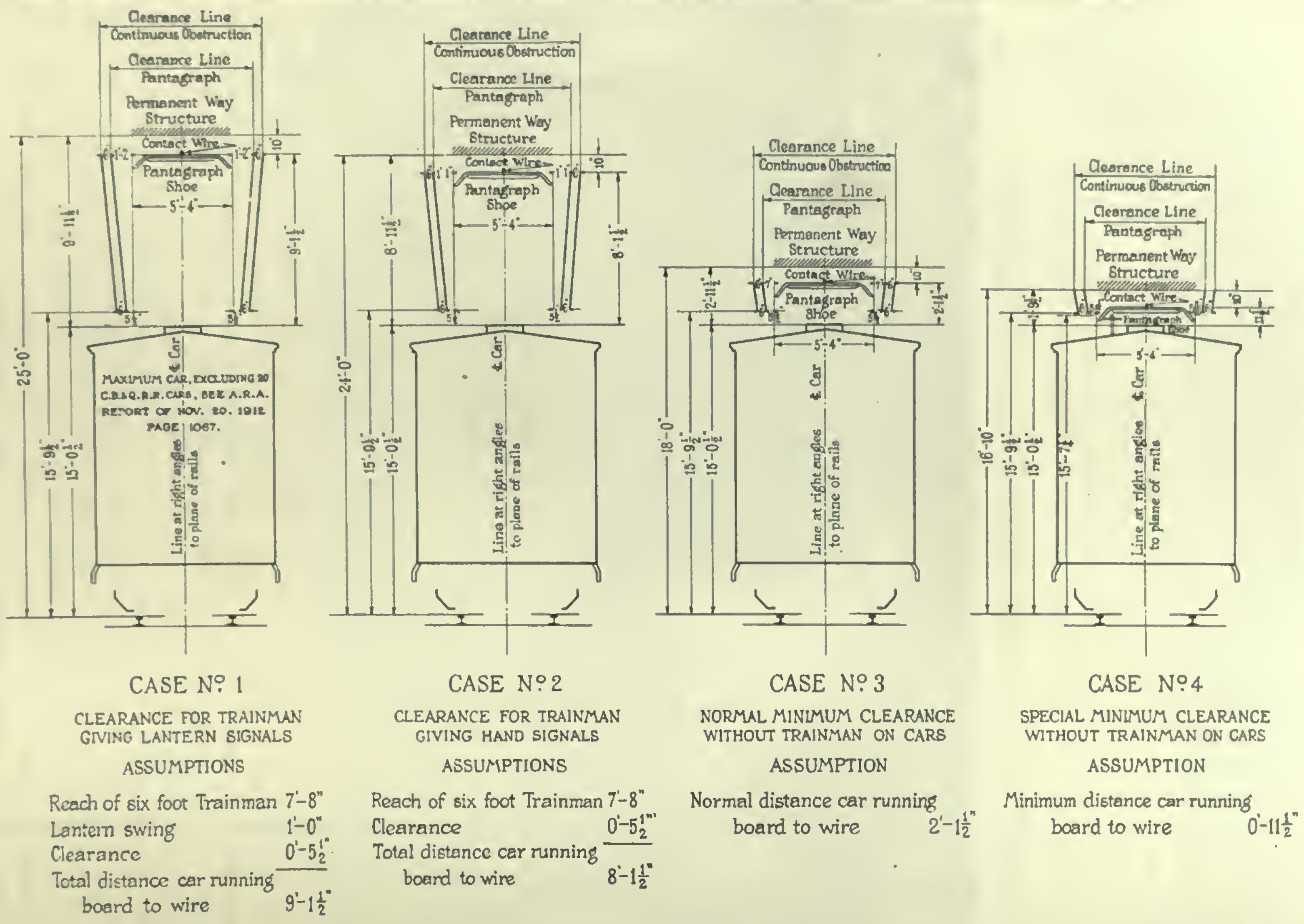


FIG. 512. YARD TRACK CONSTRUCTION, 600-VOLT OVER RUNNING THIRD RAIL
Position of Freight Cars with Reference to Third Rail, Sunnyside Yard, Pennsylvania Railroad, Long Island City, N. Y.



NOTES

Momentary obstructions such as signal blades may approach pantograph clearance line.

Sway of pantograph based on one inch difference in height of car springs, one-half inch difference in elevation of track rail and sway of six inches either side at twenty-two feet above top of rail for pantograph itself.

These diagrams show minimum clearances; additional clearances will be required to provide for special features of design, sag between points of support as affected by length of span and temperature changes, and also for steady strains, pull-offs etc., if any.

All heights to be measured at right angles to plane of rails at center line of track.

FIG. 513. AMERICAN RAILWAY ASSOCIATION'S RECOMMENDED PRACTICE FOR LIMITING CLEARANCES FOR OVERHEAD WORKING CONDUCTORS

insulators attached to the overhead structures. Suspension insulators are used with compound catenary construction, the messengers which directly support the contact wires being insulated from the primary supporting messengers at the points of suspension. The primary messenger cables are ordinarily attached directly to the supporting structures without insulation.

Two general types of supporting structures, anchor supports, or "bridges," and intermediate supports, are necessary for catenary construction. The anchor bridge performs both the function of sustaining the vertical loads due to the weight of the messengers, hangers and contact wires, and that of resisting, where required, a considerable longitudinal load. Thus, the anchor bridge provides the means for dead-ending the catenary system so that the messenger and trolley wires may be adjusted for proper tension. Devices for compensating automatically for temperature variation are sometimes used in America and quite generally in Europe. Anchor bridges are spaced at intervals, seldom greater than two miles, on main line tangent track. Shorter intervals are sometimes employed, especially in instances in which no automatic take-up device is used and also where, because of local conditions, it may be necessary or desirable to dead-end the catenary wires. Since the stresses imposed upon anchor supports are greater than those imposed upon the intermediate structures, the anchor supports are constructed of heavier sections and are designed to resist heavy longitudinal stresses. A typical anchor bridge consists of a heavy "A"-frame bent set in a concrete foundation on either side of the track and supporting a structural steel truss.

FIG. 514. OVERHEAD CONTACT SYSTEMS. Single Catenary Overhead Contact System on Curve. 11,000-Volt Single-Phase Main Line Construction, Pennsylvania Railroad, near Philadelphia, Pa.

Intermediate supports are designed to sustain vertical loads due to the weight of the catenary system, and also limited longitudinal stresses. They are placed between the anchor bridges at such intervals as may be necessary to provide the desired messenger span. Intermediate structures may be either of the bridge type or of the cross catenary type. The bridge type is a structure similar in appearance to the anchor bridge but of much lighter construction. It consists of a form of steel truss supported by two posts or

FIG. 515. OVERHEAD CONTACT SYSTEMS. Single Catenary Overhead Contact System on Tangent Track. 11,000-Volt Single-Phase Main Line Construction, Pennsylvania Railroad, near Philadelphia, Pa.

FIG. 516. OVERHEAD CONTACT SYSTEMS. Compound Catenary Overhead Contact System. 11,000-Volt Single-Phase Main Line Construction, New York, New Haven & Hartford Railroad, near New York City.

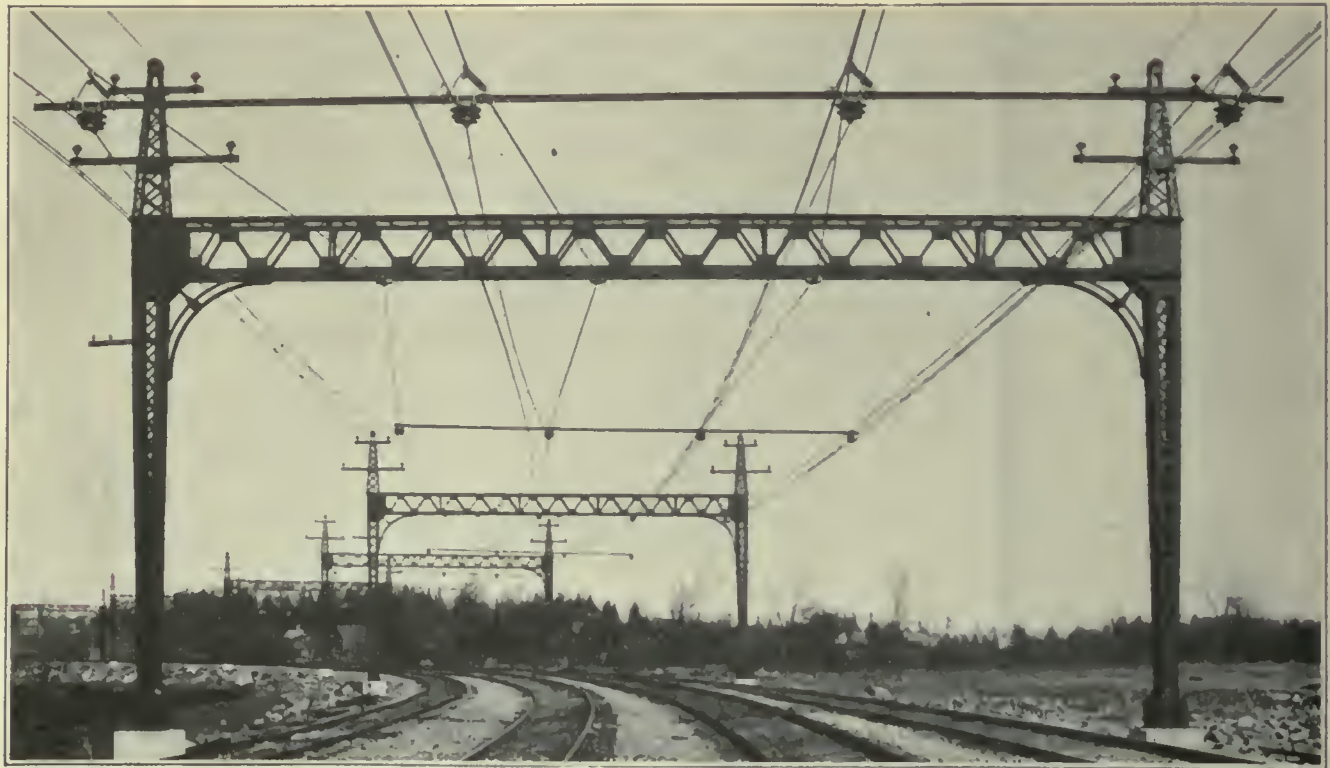


FIG. 517. OVERHEAD CONTACT SYSTEMS. Compound Catenary Overhead Contact System on Curve. 11,000-Volt Single-Phase Main Line Construction, New York, Westchester & Boston Railway, Vicinity of New York City.

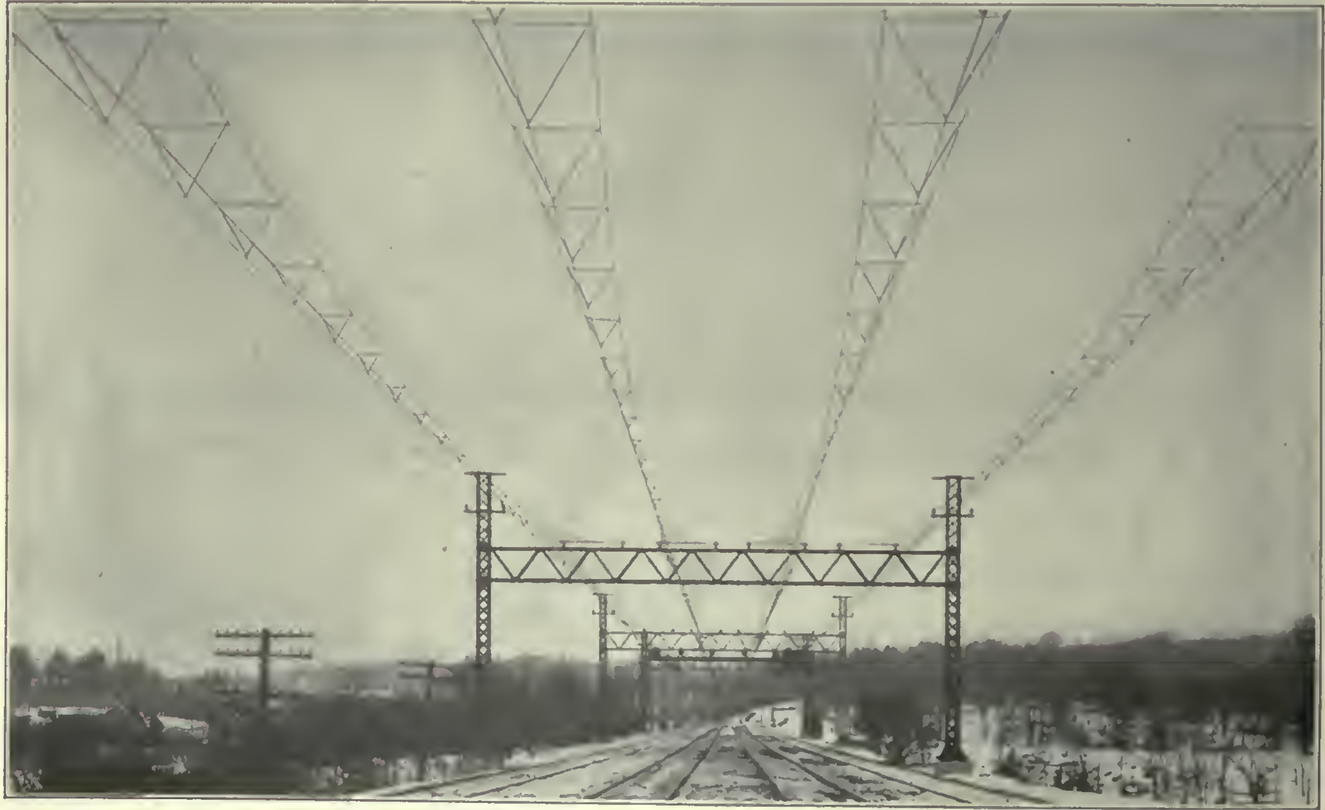


FIG. 518. OVERHEAD CONTACT SYSTEMS. Double Catenary Overhead Contact System. 11,000-Volt Single-Phase Main Line Construction, New York, New Haven & Hartford Railroad.

FIG. 519. OVERHEAD CONTACT SYSTEMS. Yard Track Construction. 11,000-Volt Single-Phase Electrification South Norwalk Yard, New York, New Haven & Hartford Railroad.

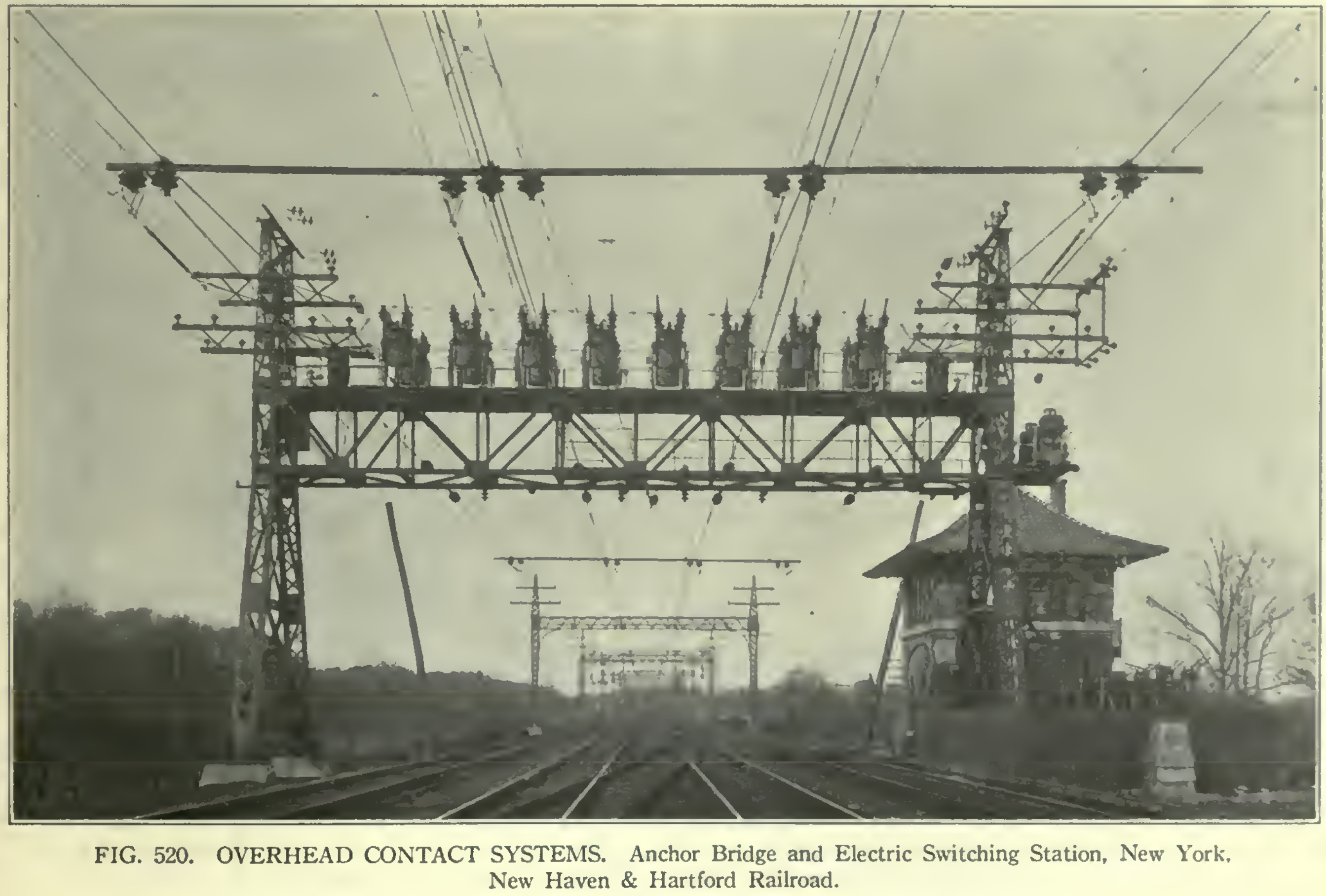


FIG. 520. OVERHEAD CONTACT SYSTEMS. Anchor Bridge and Electric Switching Station, New York, New Haven & Hartford Railroad.

FIG. 521. OVERHEAD CONTACT SYSTEMS. Yard Track Construction. 11,000-Volt Single-Phase Electrification, Harlem River Yard, New York, New Haven & Hartford Railroad

FIG. 522. OVERHEAD CONTACT SYSTEMS. Cross Catenary Span, Yard Track Construction. 11,000-Volt Single-Phase Electrification, New York, New Haven & Hartford Railroad.

bents. The cross catenary type of intermediate support consists of a cross span of steel messenger cables supported by poles set on either side of the tracks. This type of support provides a light and economical construction for intermediate structures. The messengers of the catenary system are suspended from the cross messengers by means of suspension insulators. The cross catenary type of construction is usually employed in yards, where it may be used to provide the necessary support for contact wires over many parallel tracks.

The supporting structures for the catenary have extended posts to provide supports for transmission wires, feeder wires, ground wires, signal wires and control wires. A simple type of deflector is used on the contact wire at switches.

It should be noted that the type and details of construction on American railroads differ widely, and foreign construction (which is not here illustrated) shows even greater differences in practice. In general, overhead contact construction design is in a formative stage, and considerable data from practical operation of electric railroads equipped with this form of contact are needed to standardize types and details.


FIG. 523. SWITCHING STATION ON ANCHOR BRIDGE. 11,000-Volt Single-Phase Electrification, New York, Westchester & Boston Railway.

Views of various types of overhead contact construction for single-phase operation on main tracks are shown by figs. 514 to 519, inclusive. Views of similar construction for yard tracks are shown by figs. 520 to 522, inclusive.

The voltage used on single-phase contact systems varies from 3,000 to 15,000. Experiments have been successfully conducted with alternating current at 20,000 volts on the contact wire. In the United States, the maximum potential

FIG. 524. OVERHEAD CONTACT SYSTEMS. 6,600-Volt Three-Phase Main Line Construction, Great Northern Railway, Cascade Tunnel.

used is 11,000 volts, and this value has apparently become standard for heavy electric traction. In Europe, many single-phase installations operate with 15,000 volts on the contact wire.

Means are usually provided in contact construction for the isolation of the contact wires and of the feeder wires, in case of accidents or other emergencies, by the installation of switching stations at important points. At the switching stations automatic switches are provided to open the affected circuits, thereby preventing the possibility of damage to the substation, power house or other equipment. By this arrangement, also, delays to traffic are confined to comparatively short sections of track. The switches are of the oil break type. They are located at suitable points on anchor bridges and are controlled by the operator of a nearby signal tower or by some other employe located in the neighborhood for the performance of other duties. At the points where the switches are located insulated section breaks are provided in the contact wires.

A view of a typical installation of this type of switching station is presented as fig. 523.

The three-phase alternating current system of traction employs an overhead contact supported on structures similar to those employed for single-phase systems, but requiring two contact wires above each track. These conductors are spaced from three to eight feet apart, and the distance above the tracks is governed by the same considerations as those obtaining in the single-phase system. The presence of two contact wires for each track necessarily introduces complications in the construction. The wires are insulated from each other and from the ground, since a difference of potential in the two wires equal to the contact voltage must be maintained. Catenary construction has not been generally employed with three-phase overhead contact systems, because of the added difficulty of insulating the messenger wires. The three-phase contact wires are therefore usually supported directly by flexible connections to the overhead structures or by double cross-span suspension. Spans between supporting structures are usually shorter for three-phase construction than for single-phase construction.

The complications of the overhead construction and the difficulties of insulating contact wires have led to the use of comparatively low voltages on three-phase contact wires. Existing installations have potentials varying from 750 to 6,600 volts. Experimental installations have been operated with three-phase current at 11,000 volts. The three-phase system has been more extensively used in Europe than in the United States, there being but one installation in this country. This is in the Cascade tunnel electrification of the Great Northern Railway, which employs three-phase current at 6,600 volts. In Europe, many three-phase systems operate at 3,000 volts.

A view of a three-phase overhead contact system is presented as fig. 524.

Overhead contact systems for high voltage direct current do not differ materially in design from those employed for single-phase alternating current operation. Owing to the fact, however, that lower voltages are used with direct current than with alternating current, the conductors must be of greater carrying capacity in order to deliver a given amount of power to the locomotives or motor cars. Feeders are, therefore, usually provided for direct current operation to prevent prohibitive drops in potential. Because of the

FIG. 525. OVERHEAD CONTACT SYSTEMS. Catenary Construction, 1,200-Volt Direct Current Terminal Yard, Southern Pacific Railroad, Oakland, Cal.

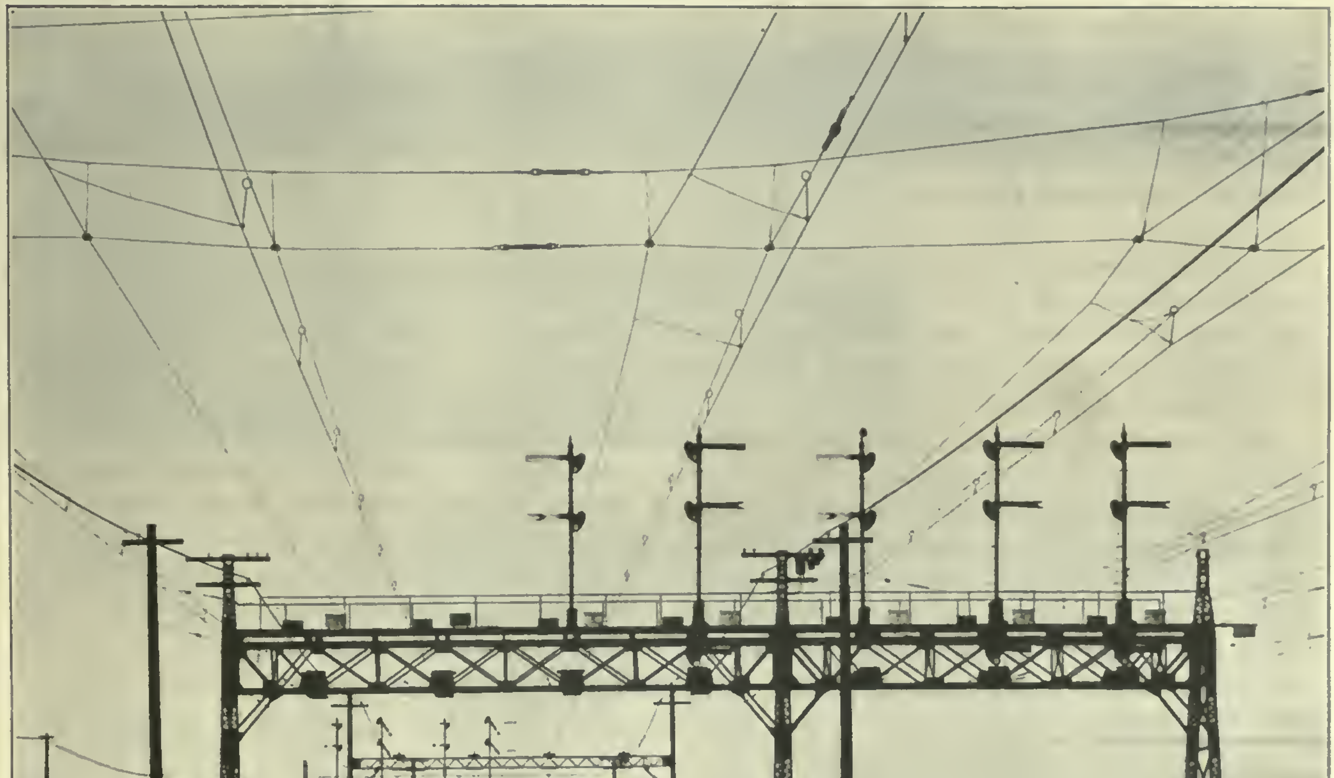


FIG. 526. OVERHEAD CONTACT SYSTEMS. Catenary Construction, 1,200-Volt Direct Current Main Line, Southern Pacific Railroad, near Oakland, Cal.

FIG. 527. OVERHEAD CONTACT SYSTEMS. Catenary Construction, 1,200-Volt Direct Current Main Line, Southern Pacific Railroad, near Oakland, Cal.

difficulty experienced in collecting heavy current from a single contact wire, it is proposed on an important direct current installation now under construction to use two copper contact wires hung from a single messenger cable.

The voltage employed on direct current contact systems is small as compared with that used on single-phase contact systems, the limitations being in the apparatus which furnishes and utilizes the electric current, and not in the contact. In the United States, direct current contact systems are operated at from 1,200 to 2,400 volts, and an installation is now under construction for operation at 3,000 volts.

Views of overhead contact systems for direct current are shown by figs. 525 to 530, inclusive.

ELECTRIC LOCOMOTIVES AND MOTOR CARS

207.19 Electric Locomotives and Motor Cars: Electric locomotives have been designed and built for all classes of passenger, freight and switching services. Motor cars have proved their value for handling passenger traffic involving frequent train movements and short runs between stops. Motor cars and trailers grouped in trains and electrically connected by a multiple system of control constitute multiple-unit trains. This system of grouping and connecting cars provides great flexibility in the make-up of trains and simplifies terminal movements in making up and putting away.

The main elements of an electric locomotive or motor car consist of the following:

1. Current collectors.
2. Control apparatus.
3. Motor equipment.
4. Driving mechanism between the motors and the wheels.
5. Body or cab.
6. Trucks.
7. Brake equipment.

The electrical features of electric locomotives and motor cars designed for the different systems of traction vary widely, although the mechanical features for the same weights and classes of equipment may be similar.

FIG. 528. OVERHEAD CONTACT SYSTEMS. Single Catenary 2,400-Volt Direct Current Main Line Construction, Butte, Anaconda & Pacific Railway.

FIG. 529. OVERHEAD CONTACT SYSTEMS. Single Catenary 2,400-Volt Direct Current Yard Track Construction, Butte, Anaconda & Pacific Railway.

FIG. 530. OVERHEAD CONTACT SYSTEMS. Single Catenary 2,400-Volt Direct Current Yard Track Construction, Butte, Anaconda & Pacific Railway.

207.20 Current Collecting Devices: Current collecting devices supply the means by which electric current is taken from the contact and delivered to the motors of the locomotives or motor cars. They consist of sliding or rolling devices adjusted to remain in continuous contact with the conductor of the overhead or third rail contact system. Two general types of collecting devices are used, namely, those for collecting current from third rail, ordinarily referred to as "third rail shoes," and those for collecting current from overhead contact wires, commonly known as "trolleys" or "pantographs."

The third rail shoes are of cast iron and are hinged to brackets mounted on wooden beams attached to the trucks of the locomotives or motor cars. The wooden beams serve to insulate the shoes from the trucks and they also provide a means of adjustment to take up wear on the wheels or shoes. The hinge device allows the shoe to remain in constant contact with the third rail despite minor irregularities in its elevation. In over running third rail installations the contact shoe is pressed down against the top of the rail by means of a spring, and in under running third rail installations a similar arrangement serves to press the shoe upward against the bottom or contact surface of the rail. In addition to the shoe contacts, electric locomotives are sometimes provided with a collector for taking current from overhead contact rails spanning gaps in the third rail alongside the track. The collector used at such points consists of a shoe placed on top of the locomotive and so arranged that when not in use it may be folded or drawn down flat on top of the cab. It is raised by springs to make contact with the overhead rail when released by the locomotive operator. Motor cars do not require this type of collector, as motor car trains are usually of sufficient length to span any ordinary gap in the normal third rail construction. Since the voltage used in third rail operation is comparatively low, elaborate methods of insulating the contact device are unnecessary. The fact that low voltage is used, however, makes heavy currents necessary and requires a relatively large area of contact between the third rail and the shoes.

The collecting device used in heavy electric traction systems in connection with overhead contact usually consists of a pantograph or a sliding bow collector. The familiar trolley with wheel, harp, pole and spring base is used only to a limited extent on steam railroad electrifications. The pantograph has a folding frame of light steel tubing, with a shoe or roller at the top and with horns extending outward and downward at both ends to prevent the contact wire from accidentally getting under the shoe or roller. The pantograph is fastened to the top of the locomotive or car by means of insulated supports. It is so arranged that, when released, it is automatically raised by springs, and it is lowered and latched by means of compressed air controlled by the motorman or engineman. The collector is held in continuous contact with the contact wire by the springs on the pantograph frame. As there is usually some variation in the height of the contact wire above the tracks, the range of extension of the pantograph is necessarily considerable. The pantograph is a high speed collector. It is very flexible and accommodates itself without difficulty to ordinary variations in the height of the contact wire. It is light in weight and the pressure exerted by it against the contact wire is also light enough to prevent undue wear.

The contact making device with which the pantograph is surmounted may be either a roller or a shoe, the roller being a thin metal cylinder which revolves about the shaft on the pantograph frame and the shoe being of channel shaped pressed steel. The shoe contact is extensively used as a collecting device for single-phase systems and the roller pantograph is frequently employed for high voltage direct current systems.

207.21 Control Apparatus: The apparatus by means of which current is furnished to the motors of locomotives and motor cars is known as the "multiple-unit control." As defined by its inventor, Mr. Frank J. Sprague,* it is a "semi-automatic system of control which permits of the aggregation of two or more transportation units, each equipped with sufficient power only to fulfil the requirements of that unit, with means at two or more points on the unit for operating it through a secondary control, and a train line for allowing two or more of such units, grouped together without regard to end relation, or sequence, to be

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* Paper read before the American Institute of Electrical Engineers, May, 1899.

simultaneously operated from any point in the train."

The current control as defined above has since been materially extended in its application. It is now used, particularly on locomotives, as a means of providing a remote control for the heavy motor currents and as a means of operating more than one unit from a single point. Two types of multiple-unit control are in general use. One of these involves the use of contactors or heavy switches in the motor circuits. These switches are electromagnetically operated by a master controller through a train line or cable. Where more than one unit is to be operated, the train line is made continuous by the use of jumper cables between units, thus connecting all contactor groups with the master controller. The master controller does not act directly, but governs the operation of the motor contactors on each motive power unit which in turn affect the switching and grouping of the motors, the resistance, or the transformer taps in the power circuit of each unit, to attain the desired operating condition. The other system of multiple-unit control utilizes air pressure for operating the contactors or unit switches. The operation of the air mechanism of the unit switches is governed by electrically operated valves controlled by the master controller through the agency of the train line. The current used in the master controller and train line for actuating the contactors and air valves of the control systems is obtained either from low voltage storage batteries or from the contact system. When the contact voltage does not exceed approximately 600 volts the current for the train line and valves may be taken directly from the line. When the contact voltage is higher, transformer taps or motor generator sets are used.

207.22 Motor Equipment: Four general types of motors are used for propulsion in electric traction systems. For direct current operation the series motor is standard. For single-phase alternating current operation the series motor, the repulsion motor or a combination series repulsion motor is used. With three-phase alternating current operation a three-phase motor is used. It should be noted that the classification of motors with reference to the different kinds of current relates to the current available at the terminals of the motors and not necessarily to the current used on the contact system.

The direct current series motor receives its name from the manner in which the windings on its armature and field are connected. It consists of an armature, field, commutator and brushes. The commutator furnishes the means of conveying the current to and from the circuits of the rotating armature through the medium of the stationary brushes. Most modern railroad motors are equipped with commutating poles in addition to the essential equipment already mentioned. These commutating poles consist of small auxiliary field poles, the winding of which is in series with the armature. The function of the commutating poles is to aid in delivering the current to the armature without harmful sparking and to allow higher voltage to be used on the commutator as a result of the production of certain magnetic effects. The series motor delivers the high initial torque necessary for starting heavy trains and operates with a wide speed range. Series motors are always operated in pairs, the control apparatus providing for suitable grouping. In starting, the two motors are connected in series and also in series with resistance which serves to reduce the voltage at the motor terminals. The resistance is cut out step by step as the speed of the motors increases. When the resistance has all been cut out the motors are connected in parallel and resistance is reinserted in series with each or with the pair. This resistance is again successively cut out as the speed further increases, until the motors are running in full parallel. Direct current series motors for 600-volt operation are quite common, having been used on most urban and interurban railroad work for many years. Such motors, insulated for 1,200 volts and connected permanently two in series, have been used for some time on 1,200-volt contact systems. Recently direct current series motors designed for 1,200 volts on the commutator and insulated for 2,400 volts, coupled permanently two in series, were placed in operation on 2,400-volt circuits.

The alternating current series motor which is used with single-phase current is very similar to the direct current series motor. In fact the single-phase series motor may be and often is operated with good results on direct current. Certain changes in the connection of armature winding leads and in the construction of the field serve to make the direct current series type of motor suitable for operation on single-phase alternating current. For equivalent rating, however, the single-phase motor is generally larger and heavier than the direct current series motor and accelerates more slowly. Single-phase motors may or may not be grouped in pairs for operation. Rheostats are not used with them but the speed is controlled by varying the voltage at the motor by means of a transformer equipped with several leads from which the different voltages may be taken.

The repulsion motor for single-phase current differs materially in its operation from the alternating current series motor, although the two machines have somewhat similar characteristics. The field or stator winding of the repulsion motor is similar to that of an induction motor. The armature or rotor is an ordinary series wound armature short circuited upon itself through the brushes. There is no electrical connection between rotor and stator windings and the power current is supplied to the stator winding only. With this type of motor it is possible to operate high voltage current on the stator winding.

Another type of motor used in electric railroad operation with alternating current is commonly known as the series repulsion motor. It is a form of repulsion motor in which the armature excites itself through a series transformer. Two sets of brushes are used on the commutator, one set consisting of the main armature brushes, which are short circuited, and the other consisting of the exciter brushes operating in the secondary circuit of a series transformer, the primary coil of the transformer being connected in the main motor circuit. This type of motor may be used with potential control or with manual control by shifting the brushes.

In America, the series motor is generally used with single-phase current. In Europe, both series and repulsion types are in extensive use.

The three-phase induction motor possesses, essentially, constant speed characteristics which limit its application for traction purposes to the operation of service with infrequent stops. Various methods have been employed to obtain limited speed variation. The motor consists of a stator with three-phase winding or windings and a three-phase secondary or rotor with windings connected to collector rings. Resistance is inserted in the rotor circuit through the agency of the collector rings, and this resistance is gradually cut out during acceleration and eliminated as the motor gains full speed. For speed variation the stator may be wound in such manner as to provide for changing the number of poles. Motors may also be concatenated or connected in cascade, so that the rotor of one motor may feed the stator of a second motor and thereby allow for half-speed operation of the two units. The operation of three-phase motors with such speed variation involves rather complicated control equipment. The induction motor may be wound for the voltage of the contact since the electric circuits of the rotor and stator are independent.

207.23 Driving Mechanism: In electric locomotive design several different types of connection between the motors and the driving wheels of the locomotive have been employed. Locomotives may be classed with reference to their driving mechanism, as follows:

1. Gearless.
2. Geared.
3. Cranked.
4. Geared and cranked.

Several modifications and combinations of these methods, employing side-rods, yokes and intermediate or jack shafts, are in use. In all designs some method is used to provide for carrying the motors wholly or partially on springs, so as to cushion the impact on the track due to the weight of the motors.

The driving mechanism of motor cars consists of geared connections between the motor shafts and the axles of the motor trucks. The motors are suspended from the axles and the truck transom and are therefore cushioned by the truck springs.

207.24 Locomotive Cabs and Car Bodies: The cab of an electric locomotive provides space for the operator and for electric apparatus. It is usually constructed of steel plates on a steel frame. Locomotives are lighted and heated by electricity, and in some cases are equipped with electric or oil heaters which generate steam for heating passenger trains.

Car bodies for motor cars are of various types and designs, the seating capacity varying with the dimensions. Modern motor cars are constructed of steel plates on steel frames with composition or wood floors. Motor cars are lighted by electricity and are usually equipped with some form of electric heater. A small compartment at either end of the car contains the control apparatus and accommodates the operator or motorman.

207.25 Trucks: Electric locomotives are classified with reference to their driving truck arrangement, as follows:

1. Rigid wheel base type.
2. Separate bogie truck type.
3. Articulated truck type.

FIG. 532. ELECTRIC LOCOMOTIVES. Electric Locomotive for 600-Volt Direct Current Third Rail Operation, Michigan Central Railroad.

The rigid wheel base types may be constructed with or without leading or trailing trucks. Separate bogie trucks may be symmetrical or unsymmetrical, the trucks being connected through the upper frames. Articulated trucks are arranged in sections with hinged connections. Guiding trucks or guiding wheels are used with high speed locomotives.

Motor cars are equipped with four-wheel trucks. Two motors are mounted on one truck, which is consequently of heavier construction than the unequipped or trailer truck. When four motors are used the two trucks are of identical design.

207.26 Brake Equipment: The brake equipment of electric locomotives and motor cars usually consists of the standard air brake apparatus used on steam trains. The supply of air is obtained from motor driven air compressors, which are automatically started and stopped when the pressure in the air reservoirs reaches certain predetermined limits. Dynamic or electric braking is possible with certain motor equipment, by arranging the motors on the locomotives or motor cars to act as generators so that they may feed back current into the distributing system on down grades and at the same time serve to retard the motion of the trains. The three-phase motor is particularly adapted to this form of braking. Such braking involves the regeneration of energy. Regeneration is, under ordinary conditions, however, more useful as a means of braking than as a means of returning energy to the line.

207.27 Locomotives and Motor Cars for Third Rail Contact Systems: Electric locomotives for third rail traction systems are equipped with contact shoes and usually with auxiliary overhead shoes for current collection. All usual types of trucks, wheel arrangements and driving mechanisms have been applied to this class of equipment. From two to eight direct current series motors, depending upon the tractive effort required, and a multiple-unit control providing for series parallel operation are used. Master controllers and operating

FIG. 531. ELECTRIC LOCOMOTIVES. Electric Locomotive for 600-Volt Direct Current Third Rail Operation, New York Central & Hudson River Railroad.

valves for brakes are located at each end of the locomotive cab. The cab also contains the motor driven air compressors, contactors, resistances and in some cases the driving motors themselves.

Views of typical electric locomotives used on third rail direct current systems are shown by figs. 531 to 533, inclusive.

Motor cars used on traction systems with third rail contact are equipped with third rail shoes on both sides of each truck. Two or four direct current series motors geared to the truck axles are employed. The motors are controlled by the multiple-unit system, which provides for series-parallel operation. Master controllers, brake valves and train signalling devices are located in each end of the car in compartments provided for the motorman. Cars are heated by electric heaters. Incandescent lamps for lighting are connected in series across the power circuit. In some cases forced ventilation of the motors is supplied by electrically driven fans mounted under the car body. This allows for operation at increased capacity by dissipating the heat more rapidly than is possible with natural ventilation. Trailer cars or cars not equipped with motors are quite generally used in connection with motor cars in trains. They are similar to the motor cars in design, and are sometimes equipped with air brake valves and master controllers to permit their use at the head of a train.

FIG. 533. ELECTRIC LOCOMOTIVES. Electric Locomotive for 600-Volt Direct Current Third Rail Operation, Pennsylvania Railroad.

Views of typical motor car trains used on third rail electric traction systems are shown by figs. 534 and 535.

207.28 Locomotives and Motor Cars for High Voltage Direct Current Overhead Contact Systems: Electric locomotives for operation with a 1,200-volt direct current overhead contact system are in use on interurban lines. Electric locomotives for 2,400-volt direct current overhead contact operation are also in use and others are under construction. With these locomotives two roller pantographs are provided for each unit. Four geared 1,200-volt motors are provided with multiple-unit control for series parallel operation, two groups of two motors being connected permanently in series. Motor-generator sets furnish current for control, for lighting and for driving the air compressor motors. Motors are ventilated by means of blowers driven by the motor-generator sets.

A view of an electric locomotive for 2,400-volt direct current overhead contact operation is shown by fig. 536.

Motor cars for a contact voltage of 1,200 have been in successful operation for several years. Pantographs of either the roller or the shoe type are used to collect current from the contact wire. The motor equipment consists of four motors, two in series for each truck. These are 600-volt motors insulated for 1,200 volts. Series-parallel operation is secured with multiple-unit control. Motor cars now under construction for use on 2,400-volt contact systems will have four 1,200-volt series motors mounted two on each truck and connected permanently in series. The current for lighting, control and air compressors in these cars will be furnished by a motor-generator set.

A view of a motor car train operating on a high voltage direct current overhead contact system is shown by fig. 537.

207.29 Locomotives and Motor Cars for Single-Phase Overhead Contact Systems: Locomotives for operation on single-phase overhead contact

FIG. 534. MULTIPLE-UNIT TRAINS. Multiple-Unit Train for 600-Volt Direct Current Third Rail Operation, New York Central & Hudson River Railroad.

systems are equipped with the pantograph or the sliding bow current collector, two collectors usually being provided for each unit. In the United States, the shoe pantograph is generally used; in Europe, the sliding bow constitutes the usual equipment. In the United States, alternating current series motors with multiple-unit control are used to the exclusion of other types, while in Europe the repulsion type of motor with manual control is giving satisfaction on some installations. The locomotive for operation on single-phase systems is equipped with a transformer placed in the cab. Apparatus for forced ventilation is supplied for cooling the transformer and the motors. Existing single-phase systems employ locomotives of various truck arrangements and driving mechanisms, the equipment usually being designed and constructed to meet the peculiar needs of the individual installation.

A type of locomotive termed the "split-phase" locomotive has recently been built for use with the single-phase overhead contact system. With this equipment three-phase motors are used for driving the locomotive. Single-phase current is collected by pantographs and stepped down to the proper voltage for the phase converter. The phase converter consists of a rotating machine similar in appearance to a three-phase motor. It converts the single-phase current collected by the pantograph to three-phase current which is utilized by the three-phase driving motors.

Views of electric locomotives constructed for operation on single-phase alternating current traction systems are shown by figs. 538 to 540.

A type of locomotive has recently been constructed which receives single-phase alternating current from the contact, steps it down to a working voltage by means of a transformer, and converts it to direct current by means of a mercury-vapor rectifier, this rectified current being utilized in direct current series driving motors.

Motor cars for operation on traction systems employing single-phase overhead contact are equipped with bodies and trucks similar to those used with direct current overhead contact. Shoe pantographs are employed for collecting the high voltage current, which is conveyed through oil switches to transformers located underneath the cars. Taps from these transformers permit a variation in the voltage of the current delivered to the motors, which in turn produces a variation in the speed of the motors. Two or four motors are used on each car and are controlled by the multiple-unit system. Current for lighting, heating and operating air compressor motors is obtained from special taps on the transformers.

Motor cars have been built for operation on both 600-volt direct current circuits and on high voltage single-phase alternating

FIG. 535. MULTIPLE-UNIT TRAINS. Multiple-Unit Train for 600-Volt Direct Current Third Rail Operation, Long Island Railroad.

FIG. 536. ELECTRIC LOCOMOTIVES. Electric Locomotive for 2,400-Volt Direct Current Overhead Contact Operation, Butte, Anaconda & Pacific Railway.

current circuits. Cars of this type are equipped with shoes for third rail contact or with pole and wheel trolleys for the low voltage overhead contact, and with the pantograph for the high voltage overhead contact. Series motors with change over switches and double control are employed.

A view of a typical motor car train used on a single-phase alternating current system with overhead contact is shown by fig. 541.

207.30 Locomotives and Motor Cars for Three-Phase Contact Systems: Locomotives for operation on three-phase traction systems are equipped with double contact sliding bow current collectors or with two sets of pole and wheel trolleys. Three-phase motors, with and without pole changing or cascade speed variation equipment, are operated either with multiple or manual control. This class of locomotive has been used on several installations in Europe and on the Cascade tunnel electrification of the Great Northern Railway in the United States. Most of the European three-phase locomotives have motors wound for the contact voltage and have a crank and side-rod driving mechanisms. The locomotives of the Great Northern Railway have transformers for stepping down the contact voltage for use on geared motors.

A view of an electric locomotive used on a three-phase system of electrification is presented as fig. 542.

Motor cars for operation with three-phase contact systems are used to a limited extent in Europe. Owing, however, to the constant speed characteristics of the three-phase motor, no new equipment of this type has been constructed in recent years. Motor cars of this type have not been used on any electric traction systems in the United States.

207.31 Return Circuit: The return circuit of an electric traction system is the link in the system which serves to complete the electric circuit between the locomotives and motor cars and the points at which the current is fed into the contact system. The track rails are generally used for the return circuit, since it is desirable from a standpoint of economy to utilize the conductivity which they afford. Several electric

FIG. 537. MULTIPLE-UNIT TRAINS. Multiple-Unit Train for 1,200-Volt Direct Current Overhead Contact Operation, Southern Pacific Railroad.

traction systems in England are equipped with an independent or separate return circuit known as the "fourth rail." These installations are operated with the third rail direct current system of traction, the locomotives or motor cars being equipped with shoes for delivering the return current to the fourth rail in addition to the usual equipment required for third rail systems. The use of the fourth rail return is dictated by the necessity of meeting certain rules of the English Board of Trade.

FIG. 538. ELECTRIC LOCOMOTIVES. Locomotive and Train for 11,000-Volt Single-Phase Overhead Contact Operation, New York, New Haven & Hartford Railroad.

Ordinary railroad track offers a high resistance to an electric current unless provision is made for connecting the individual rails making up the track. This is accomplished by bonding the joints. Many methods have been developed for bonding track rails. Track bonds may be classified broadly as protected and unprotected types. The bonds are made of copper wire, cable or ribbon, with terminals soldered, brazed or welded to the rail or expanded in holes in the web of the rail. Bonds are said to be protected when they are installed under the angle bar or device employed for fastening the rails at joints, and unprotected when they are installed outside of the angle bar. Bonds vary in length from a few inches to several feet, depending upon the type of bond and upon local conditions. Frequently very long bonds are required at points where special track work is used. It is customary also to bond the rails of parallel tracks by installing cross bonds at points where there is no danger of deranging track signal circuits.

The cross-section of the bonds installed and the number of bonds per joint are varied according to the local or the electric conditions to be met. Double bonding is generally employed on important tracks, either to insure the conductivity of the joint or to meet conditions of track construction which will not permit the use of a single bond of desirable conductivity. Return feeders are frequently used on traction systems to reinforce the track circuit and to reduce the voltage drop. These return feeders are usually copper cables run from the substation to desired points and connected to the track rails at short intervals.

FIG. 539. ELECTRIC LOCOMOTIVES. Switching Locomotive for 11,000-Volt Single-Phase Overhead Contact Operation, New York, New Haven & Hartford Railroad.

207.32 Electrolysis: The return current flowing in the track rails causes a voltage drop, or a difference of potential, between the track at or near substations or other feeding points and the track at places remote from such

FIG. 540. ELECTRIC LOCOMOTIVES. Locomotive for 11,000-Volt Single-Phase Overhead Contact Operation, Norfolk & Western Railway.

points. This difference of potential permits a portion of the electric current to leave the track rails and return to the substations through the earth or through metallic conductors such as water pipe, gas pipe or cable sheaths. At points where the current leaves such metallic conductors electrolysis occurs. In the case of direct current, electrolysis may cause serious damage to the conductor; in that of alternating current, its effect is negligible. Several means of overcoming the effects of electrolysis have been successfully employed on existing direct current traction systems. The installation and maintenance of good bonding at rail joints, and insulated negative feeders between the track and the substation, are usually employed for this purpose. Boosters are sometimes installed in these feeders to overcome the necessity for using an excessive amount of copper.

In cases where the difference of potential in the track is sufficient to cause damage, insulated joints are sometimes installed at intervals in the pipes or cable sheaths affected, so as to increase their resistance and thereby reduce the flow of return current through them. Unless a careful survey is made preparatory to installing the insulated joints, damage may still occur at such points. Pipe or cable drains consisting of insulated feeders connecting the pipes or cables with the substations are also used. The plan of providing metallic connectors between the track rails and the cables or pipes, although often followed, is not now generally approved.

The English Board of Trade requirements limit the difference of potential in any part of the track to seven volts. In order to meet this requirement, some of the electric railroads in London use an insulated "fourth rail" for the return.

207.33 Inductive Interference: Alternating current flowing in a wire sets up a magnetic field around the wire which induces an alternating electromotive force in other wires approximately parallel to the primary wire. The amount of this induction varies with the length of the exposure and the amount of current flowing, and is much less if the parallel wire is remote from the primary wire. Where two or three wires constitute the single-phase or three-phase circuit

FIG. 541. MULTIPLE-UNIT TRAINS. Motor Car Train for 11,000-Volt Single-Phase Overhead Contact Operation, New York, Westchester & Boston Railway.

used for transmitting power, and where the wires are mounted as close together as physical conditions and insulation requirements will permit, the direction of current in the several wires of the circuits is such that the electromotive force induced in foreign wires is practically neutralized.

When the wires of the circuit are separated at considerable distance, as, for example, when the earth is to be used for the return circuit, this neutralizing effect of the return is largely lost and, under certain conditions of load and distance, voltages sufficient to cause serious disturbance in telephone and telegraph circuits are induced.

With a direct current traction system the alternating current is confined to the transmission line, all wires of which are mounted on poles so close together as practically to neutralize the induction, but under certain conditions, such as in instances where one leg of the transmission circuit becomes grounded and the current returns through the earth, inductive disturbances are likely to occur. These being only emergency conditions, however, which may be quickly cut out by the action of automatic switching devices, they may be considered as momentary. Inductive disturbances may, in general, be said to obtain only with alternating current traction systems using track and earth as return.

FIG. 542. ELECTRIC LOCOMOTIVES. Locomotive for Three-Phase Overhead Contact Operation, Great Northern Railway.

Experience with alternating current systems and tests of special appliances for overcoming induction have developed the following remedies:

1. The installation of neutralizing transformers in the telephone and telegraph circuits together with primary wires for the same placed on the pole line.

These transformers induce opposing or neutralizing electromotive forces in the telephone or telegraph lines and serve to minimize the effects of the induction. The use of such transformers, however, introduces complications, especially in telephone circuits, and adds something to the cost of maintenance and operation of the lines. It will be found preferable, therefore, to employ other methods in dealing with this difficulty.

2. An arrangement of feeding points (transformer substations) along the line of railroad at intervals sufficiently frequent to make the distance over which current must be transmitted comparatively small.

When the length of line supplied from an individual feeding point is short, the amount of current flowing is reduced to a portion only of that drawn by the train between substations, since the current is supplied to the train from opposite directions. The product of the current and the distance through which it flows from either substation to the train is such as to make the induction in the two parts practically equal, and as they oppose one another the resulting induction is small. Transformers also are placed near the stub ends of lines, so that the distance over which the current must be fed in one direction for the stub end section is small.

This constitutes a satisfactory treatment for normal service conditions, but inasmuch as a substation may occasionally, in emergencies, be cut out entirely and the current fed from the adjacent substation or from the second substation, the induction may under such circumstances become sufficient to cause disturbance. Likewise, when short circuits occur at certain points, the heavy flow of current may momentarily cause inductive disturbances until the automatic switching devices are opened.

3. The installation of series or booster transformers at intervals along the line, the primary being connected in the trolley circuit and the secondary in track rails or parallel feeder.

Such transformers are designed for a voltage which will be sufficient to keep the return current in the track rails or return feeders and out of the earth, thus producing conditions which are practically or nearly equivalent to an insulated return. Under this condition, the induction is negligible in a wire equally distant from the trolley and the conductor which carries the return current. If the wires are not equally distant from the outgoing and return current conductors, the induction may be reduced by a suitable adjustment of the ratio of the windings on the booster transformers.

The first remedy described is for the purpose of neutralizing or overcoming induction set up in the telephone and telegraph wires; the second and third are for the purpose of preventing such induction from being set up in the wires, and are therefore preferable.

In addition to the electromotive forces induced in telephone and telegraph lines by the traction currents, there are sometimes superimposed on the fundamental current wave-form high frequency harmonics due to a variety of conditions in the electric apparatus and system. These tend to produce noise in telephone instruments connected to parallel wires. Where the fundamental induced electromotive forces are kept low, the high frequency alternations are also relatively of small magnitude. A great deal has been accomplished by giving careful attention to the details of design and construction of the alternating current machinery used and, with a properly designed system using booster transformers and a sufficient number of feeding points, comparatively little trouble is to be anticipated from noise. However, if in special cases objectionable noise is found to exist, it can be neutralized and remedied by placing the telephone wires in cables where the two wires of the telephone circuit can be accurately paralleled and transposed by twisting, thus neutralizing the effect of high frequency current waves.

207.34 Miscellaneous Equipment: The essential elements of an electric traction system have now been described. Additional equipment and devices are, however, required for the economical and efficient operation of any system.

A comprehensive telephone equipment is required to furnish means of intercommunication between the power station, substations, repair shops, inspection sheds, and stations or towers from which switching apparatus is controlled. On railroads handling heavy traffic an extension of the telephone system is necessary, in order to provide emergency stations at short intervals along the track, from which patrolmen or inspectors may communicate with headquarters.

Certain work and emergency equipment is necessary for the inspection and maintenance of electrified tracks. Gasoline-driven inspection cars are generally used by inspectors of contact conductors and transmission lines to facilitate their work. Self-propelled repair trains are required for emergencies. Repair trains for service on roads using the overhead contact system must be equipped with towers or with adjustable platforms to accommodate workmen repairing the contact line. On railroads using the third rail contact system, the emergency equipment includes cars provided with apparatus for spraying the third rail with a solution of calcium chlorid to prevent the formation of sleet during storms.

Sheds, pits and repair shops are required for the inspection and repair of locomotives and motor cars. Inspection sheds must have pits underneath and between tracks to allow workmen to examine and repair motor and control equipment under the cars. Repair shops require an assortment of machinery and equipment for handling work which cannot be done at the inspection sheds.

Tracks on which signal systems are used must be provided with impedance bonds at the ends of each block, their function being to allow the flow of the return current and, at the same time, to interrupt the track signal circuit and confine it to individual blocks. With all systems of electric traction the track signal circuits, if used, employ alternating current. For alternating current systems of traction, the current employed for signal circuits is of different frequency from that used in the traction circuits, and impedance bonds may be designed to permit the flow of the propulsion current while preventing the flow of the signal current.

208. TECHNICAL FEASIBILITY OF THE ELECTRIFICATION OF THE CHICAGO RAILROAD TERMINALS

SYNOPSIS: Careful consideration has been given matters affecting the technical feasibility of electrification as applied to the Chicago terminals. This chapter presents a discussion of these, and ends with a series of conclusions which, while frankly recognizing the difficulties to be met in installing and operating any single system for all the different services of the terminals, are to the effect that electrification is technically feasible.

208.01 Purpose: All proposals designed to bring about the elimination of the steam locomotive from the city of Chicago. necessarily involve the practicability of introducing some other form of motive power capable of performing the service now rendered by the steam locomotive. Those who have considered the subject have generally assumed that this could be accomplished through the complete electrification of the railroad terminals. Previous discussions (chapter 204) have shown that there exists no other form of motive power, capable of handling as a whole the traffic of the Chicago railroads, which could be substituted for the steam locomotive. The question as to whether complete electrification is practicable from an engineering standpoint has not yet been discussed. It is a fundamental one and as such it requires careful consideration.

For the purpose of this report, electric traction on the railroads of Chicago may be said to be technically feasible when all the elements of the selected system, individually and collectively, are capable of performing the required service safely and reliably, and when it has been found possible to apply them to the local traffic and to the physical conditions of the terminals. Technical feasibility therefore involves:

1. The successful functioning of apparatus from electrical and mechanical standpoints.
2. Permanency in the design or type of the various elements of the electric traction system under consideration. Any system which might, in a short period, become obsolete or out of date, due to the rapid evolution of the art, could not be regarded as technically feasible.
3. Successful application of apparatus to an existing property without radical change in the physical characteristics of the property.
4. Successful application of apparatus to an existing property without requiring operating changes which might impair the usefulness of the property either to its owner or to the public.

Technical feasibility is closely related to the problem of finance, since any proposition that is financially absurd cannot be accepted as technically sound. It is the present purpose, however, to discuss technical considerations only, leaving for a later chapter the questions of financial practicability.

208.02 Characteristics of the Terminals as Related to Technical Feasibility: Any discussion of technical feasibility must be based upon a correct understanding of the extent and character of the establishment to be dealt with. A description of the present steam railroad terminals of Chicago, the character and extent of their traffic and train movements and a discussion of their rate of growth, have already been presented (chapters 201, 202 and 203). The facts set forth in these chapters and in a subsequent chapter (209), relating to the extent of the plan of electrification as it affects individual roads, define the character of the terminals and their relation to their environment and constitute a measure of the problem to be solved by any plan of electrification.

The Committee has sought to accept the problem as thus defined. While it has recognized the possibility of rearranging certain facilities of the railroads in the city and of combining, eliminating and otherwise simplifying trackage and traffic movements, it has not dealt with such problems. The basis of its investigation concerning the technical feasibility of electrification is to be found, therefore, in conditions as they existed in 1912, the Committee's statistical year.

208.03 The Diversity of Interests Involved: The terminals of Chicago represent many different interests. A single railroad corporation, having only itself and the public to satisfy, may enter upon any work of betterment by procedures comparatively simple. A number of railroad corporations, however, proposing to join in any such work, are immediately confronted by complications not only in administration but in the acceptance of principles and standards affecting technical procedure. The problem of electrification as applied to the Chicago railroad terminals involves the interests and physical organizations of 37 separate railroad corporations. If the terminals of these separate railroads are to be electrified, the highest degree of efficiency is to be gained through joint procedure. It is inconceivable that the different railroads will undertake such a work independently. It may be argued that a procedure necessary in the case of one railroad may prove quite unnecessary in the case of another, and yet the fullest measure of technical success in the electrification can be secured only when individual interests and preferences are subordinated to the requirements of a general plan. Efficiency in installation and quality in the work to be accomplished make joint action desirable and, from a technical point of view, almost necessary. However, the manner in which such action is to be secured is by no means easy to determine.

In addition to the railroad corporations, other interests are concerned with any plan of electrification. Many private industries own a considerable mileage of track within the terminals. This track, in common with that of the railroad companies, must be electrified. These industries will be confronted with the necessity of materially changing structures and other facilities before service now rendered by steam may be performed electrically, and their interests must be taken into account in determining the technical procedure.

The number of interests involved is thus seen to have an important bearing upon the question of technical feasibility. If each individual interest were to attempt to approach and solve the problem of electrification of itself and for itself without reference to the plans and interests of its neighbors, there would be justification for the conclusion that electrification is not technically feasible. If, on the other hand, it may be assumed that in working out the problem of electrification a community interest will be recognized and that certain phases of the whole work will be undertaken through joint action, to the end that the work when completed may be reasonably uniform in system and in standards of construction, the foundation is laid upon which to proceed with the consideration of other details affecting technical feasibility.

208.04 The Extent of the Terminals: The mere extent of an undertaking involving engineering design and construction is not necessarily a factor affecting technical feasibility, but magnitude adds complexity. In its approach to this problem the Committee has assumed—

1. That all the railroad tracks in the city are to be included in the plan.
2. That the limits of the electrified trackage as determined for each railroad are to be fixed at points as near the limits of the city as may be practicable.

The trackage involved by this conception may be summarized as follows:

	MILES
1. Main track	1,475.59
2. Yard track	1,456.64
3. Industrial track owned by railroads	277.19
4. Industrial track owned by industries	229.72
5. Industrial track, railroad repair track and shop track, so located in streets at grade, in buildings or under structures employed in industrial processes as to require special classification	37.26
Total	3,476.40

The trackage represented by item 5, about one per cent of the total, is so located with reference to existing structures or activities that it is judged to be technically impracticable to include it in any general scheme of electrification.* In the event that general electrification is found to be technically feasible, it is assumed that the trackage in question will be operated by self-propelled motive power units such as steam locomotives or some of the several types of locomotives described in chapter 204. Its exclusion leaves the extent of trackage to be further considered in discussions concerning technical feasibility as follows:

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* This trackage cannot be equipped and operated with any form of overhead contact. It is later shown (section 208.12) that the trackage which cannot be equipped and operated by third rail is about twice this amount.

	MILES
Total trackage	3,476.40
Technically impracticable because of environment	37.26
Trackage to be considered in the further study of technical practicability	3,439.14

208.05 The Diversity and Magnitude of the Traffic: The Chicago terminals embrace all classes of steam railroad service. The various activities of the terminals, in terms of traffic and train movement, have been set forth in chapter 202. The following services are represented:

1. Through passenger.
2. Suburban passenger.
3. Road freight.
4. Yard.
5. Freight transfer.
6. Passenger transfer.

The last three classes named are commonly denoted as switching service but for reasons elsewhere explained the above subdivisions are made. The extent of the traffic represented by these services in 1912 in the Area of Investigation was:

1. THROUGH PASSENGER SERVICE	
Number of railroads operating this service	23
Average number of through passenger trains handled per week day	579
Service on average day in October, 1912, locomotive-miles	11,430
Per cent of all services	15.8
2. SUBURBAN PASSENGER SERVICE	
Number of railroads operating this service	13
Average number of suburban trains handled per week day	793
Service on average day in October, 1912, locomotive-miles	12,296
Per cent of all services	17.0
3. ROAD FREIGHT SERVICE	
Number of railroads operating this service	25
Service on average day in October, 1912, locomotive-miles	5,756
Per cent of all services	8.0
4. YARD SERVICE	
Number of railroads operating this service	39
Service on average day in October, 1912, locomotive-miles	30,790
Per cent of all services	42.5
5. FREIGHT TRANSFER SERVICE	
Number of railroads operating this service	32
Service on average day in October, 1912, locomotive-miles	10,993
Per cent of all services	15.2
6. PASSENGER TRANSFER SERVICE	
Number of railroads operating this service	16
Service on average day in October, 1912, locomotive-miles	1,083
Per cent of all services	1.5
Locomotive-mileage for all switching services, items 4, 5 and 6, on average day in October, 1912	42,866
Per cent of all services	59.3

The preceding facts are all significant in their relation to technical feasibility. No undertaking in electrification involving the same magnitude and variety of movements has ever before been attempted. The most extensive service of the terminal is the switching service, and thus far switching movements have not been handled extensively by electric motive power units. The electric operation of switching yards will therefore involve a series of new procedures, the technical significance of which will be hereinafter discussed.

208.06 Technical Feasibility as Disclosed by Electrifications Elsewhere: The first demonstration of heavy electric traction was in the Baltimore tunnel of the Baltimore & Ohio Railroad, where heavy trains were moved at slow speeds for short distances and at infrequent intervals. In spite of the disadvantages to which a pioneer installation is necessarily exposed, this installation has been kept in operation and continues to serve its purpose. Its work goes far toward demonstrating the technical practicability of conveying and utilizing heavy currents such as are required for operation under steam railroad conditions, although economically the electrification has been a burden justifiable only because of local (tunnel) conditions.

A demonstration of the success of electric traction for moderately long but light passenger trains on city elevated railways, where steam locomotives operating overhead in the streets were obviously objectionable and where an increase in the capacity of the lines was essential, followed the demonstration at Baltimore. In this development electric locomotives were not used, propulsion being secured through motor-car units distributed throughout the train. Such an arrangement constitutes, in effect, an extension of trolley motor car operation by controlling several cars simultaneously from the head end. This development led to improved methods of transmitting large amounts of power from a central source and of collecting, controlling and regulating it at the trains.

Next came the elaborate development of subsurface terminals in large cities in which electric propulsion was substituted for steam locomotive propulsion because of the impracticability of using steam in tunnels and underground stations;

then, the application of electric locomotives to heavy freight and passenger service in long tunnels for the purpose of avoiding operating difficulties and dangers incident to the use of steam; and finally, the application of electric traction in heavy mountain grade main line work for the purpose of increasing the capacity of the line and utilizing available hydro-electric power.

Experience thus gained has demonstrated that:

1. Trains of any weight can be hauled electrically at any required speed, provided the necessary amount of electric power can be conveyed to the train motors.
2. Where appliances can be properly installed and maintained, in view of local conditions, electric traction has been found to be reliable.
3. Under ordinary railroad conditions the introduction of electricity does not materially affect the hazard of railroad operation.

These general conclusions are supported by the testimony presented in other chapters of this report (205, 302 and 303).

208.07 Feasibility of the Elements of Electric Traction Systems: All electric traction systems have certain common elements, these being:

1. The power supply (power station).
2. The means of conveying the power to local points (transmission lines).
3. The means of converting and regulating current (substations).
4. A contact device serving the tracks (third rail or overhead construction).
5. The rolling equipment (train motors).
6. The return circuit (in track rails).

The technical feasibility of applying these several elements, under conditions which are presented by the railroad terminals of Chicago, may now be discussed.

208.08 Power Supply: The amount of energy required to operate electrically the railroad terminals of Chicago, while large, is not so great as to justify the expectation that unusual means must be employed to supply it. Reviewing the possible sources of such supply, the following may be noted:

Large undertakings of the kind have often been stimulated by the availability of water power. Chicago has no available water power in proximity to the proposed electrification. While the transmission of electric energy to Chicago from a remote source of water power, such as might be supplied by the Mississippi River, is possible, a normal procedure would not permit this city to receive energy from such a source until communities nearer to it had been supplied. Aside from the fact that the intervening territory is thickly populated and its demands are likely to exceed the supply even of such a source, an electric transmission line of approximately 250 miles in length, although of the best construction, would constitute a weak link in the whole project of railroad electrification. The possibility of obtaining energy for the electrification of Chicago's railroad terminals from water power cannot, therefore, be considered. Such energy must necessarily be derived from fuel.

A supply of electric energy direct from the coal fields would constitute an ideal arrangement from the standpoint of smoke abatement since it would entirely remove from the city the necessity for the handling and burning of the fuel which would otherwise be required to generate the necessary power at a plant located in Chicago, or approximately 808,000 tons of fuel per annum. The argument, however, against the remote production and long distance transmission of energy as affecting the reliability of the service, applies as well in this case as in the suggested possibility of securing power from a remote hydro-electric plant. It must be concluded that, under present conditions, it will be better to transmit potential energy to Chicago in the form of fuel than in the form of electricity. Preferably the center of power supply should be located as near as practicable to the center of distribution to the motive power units.

The supply of electric energy for railroad traction through the purchase of power would in no wise complicate nor in any large way simplify the general question of technical feasibility as applied to the electrification of Chicago's railroad terminals as a whole. The purchase of power from a public utility corporation is a question to which the Committee has not given detailed consideration. For the present, it will suffice to note that whether the railroads secure electricity by generating it themselves or by purchasing it is, in its larger aspects, a question primarily of administration. The problem of producing the electric energy, except as affected by various incidental considerations to be hereinafter noted. will in either case remain the same.

In the further discussions of this report it is assumed, for reasons which will be apparent, that the railroads will, in the event of electrification, provide their own facilities for the generation and distribution of power. Such an assumption by the Committee, designed to serve its peculiar purposes, is not intended to constitute an expression of opinion as to what, in the event of electrification, the actual procedure should be.

Similarly, questions affecting the design and equipment of the necessary sources of electric supply which shall determine whether each railroad should furnish its own energy or all the railroads should co-operate in unified control of one or two large power generating stations, are primarily questions affecting the first costs and operating results of electric traction. A discussion of these is necessarily predicated upon the assumption that the generation of current for the purposes of railroad electrification is technically feasible.

It is evident from the preceding discussion that, while questions of great importance are introduced through the necessity of developing a source of electric energy sufficient to operate the railroads of the terminal and while the settlement of these questions will certainly find many differences of opinion, there is, from a technical point of view, no serious difficulty in accomplishing this end.

208.09 Transmission System: The problem of transmitting electric energy from the point of generation to the points of distribution along the rights-of-way of railroads is a problem upon which there are likely to be few differences of opinion. It presents no serious technical difficulties. The efficient transmission of electric energy normally involves the use of alternating current at high potential. The Committee has assumed that transmission lines will in all cases be of open wire construction on steel poles along the rights-of-way of railroads and that current will be transmitted at 33,000 volts.

The use of the rights-of-way of the railroads for transmission lines of this character and potential will confine the lines to private property and will facilitate construction, inspection and maintenance. The type of construction proposed will provide a relatively safe installation.

208.10 Substations: The proposal to electrify the Chicago railroad terminals involves the consideration of problems of transforming, converting and regulating large amounts of power at substations for systems employing direct current on their contact; or of transforming and regulating large amounts of power at substations for systems employing single-phase current. The problems of the substations, however, will not be particularly difficult—as the principles involved are all covered by existing practice.

208.11 The Importance of a Co-operative Procedure in Generating and Distributing Power for Chicago's Railroad Terminals: From the preceding it may be concluded that it will be technically feasible, in the event of electrification, for each individual railroad to provide its own power station, transmission lines and substations. Such a solution, however, would not give an installation which would meet the requirements of present-day standards governing such matters.

Of the 39 railroads operating in Chicago, 37 will be involved in any general scheme of terminal electrification. All except one of these have tracks for which electric power will be required, but a procedure by individual railroads which would result in the development of 36 different power stations located at various points would, from a technical and economic point of view, present an unfortunate solution of this detail of the whole problem. The combined capacity and consequently the first cost of such a series of individual power stations would be greatly in excess of the capacity and cost of a single power station designed for joint use, and the operating costs of the 36 separate power stations would be greater than the operating costs of the single joint station.

Similarly, the distribution of energy through the medium of individual transmission lines and individual series of substations would constitute a much more complicated solution of the general problem than the conditions warrant. Substations would, in many localities, constitute clusters of facilities which, except for the requirement of individual treatment, could be better embodied in a single facility. The combined capacity and consequently the cost of such a group of substations would be greatly in excess of that of a joint substation and the cost of operation and maintenance would be relatively large.

The difficulties and the weaknesses inherent in a solution of the problem of power generation and distribution through the agency of individual roads disappear at once when joint development is assumed. A single power station, or perhaps two stations, designed and operated for the joint use of all roads, and a single system of transmission lines and substations with only such duplication as may be desirable to insure continuity of service for all roads, would reduce the whole problem of power generation and distribution to its simplest form and would operate greatly to increase the technical feasibility of this aspect of the electrification problem.

The determination to provide for the joint use of such facilities would do more than promote efficiency in installation and operation; it would insure to all the railroads of the terminal uniformity in certain fundamental methods and equipment which in the absence of such procedure might be given varying forms and might lead to a diversity of standards.

The development of facilities for the generation and distribution of power for the joint use of all railroads embraced by the activities of Chicago's terminals can only be secured through the development of a co-operative relationship between the railroads concerned, and hence the ability of the diverse interests involved in any plan of electrification to agree in matters of detailed procedure constitutes an important aspect of the problem of technical feasibility.

208.12 Contact System: This element of an electric traction system is by far the most important in its relation to the question of technical feasibility. In fact, the choice of the form of contact conductor may determine whether electrification is technically practicable or impracticable.

The contact system involves a continuous charged conductor alongside or above each track equipped for electric operation. The design and installation of a suitable contact conductor even for simple conditions require careful attention, and as the scope of the electrification plan is extended the difficulties attending the installation of a workable and properly safeguarded contact conductor are increased. The Chicago terminals present, as the outgrowth of physical obstructions and traffic requirements, conditions which are unprecedented in complexity and magnitude, and these conditions offer many difficulties affecting the application of any single form of contact system.

Electrical Sufficiency

This phase of the subject need not here be discussed in detail. It has already been shown (chapter 205) that sufficient power can be transmitted to moving trains either by means of a third rail alongside the track or by an overhead wire. The technical features of voltage and insulation have all been solved by the successful operation of existing installations.

Protection

Contact conductors for all systems must necessarily be so located that contact may be maintained with the rolling equipment. They must present at least one exposed surface to permit the maintenance of a continuous electric contact with sliding devices attached to the moving train. The currents employed in electric traction are of such potential as to be dangerous to life. The question, therefore, of protection to the public and to employes against accidental contact with these electrically charged conductors assumes importance. It is desirable that all parts of the system which may have a difference of potential between them and the ground, be either placed out of reach or be protected, to remove the possibility of accidental contact.

In the case of the third rail the current carried is of a potential sufficiently high to cause fatalities upon contact under certain conditions. A momentary contact, however, produces only a shock which, unless it causes a person to fall on the charged conductor, will not usually prove fatal or even permanently disabling. Such protection as it is feasible to provide for third rail construction will materially reduce the danger of accidental contact but, as will be shown later, (chapter 303) there are certain conditions under which even a protected third rail may be dangerous to employes performing their duties and especially dangerous to trespassers. For this latter reason it is necessary that all right-of-way of railroads, the tracks of which are equipped with third rail, be securely fenced.

In the case of overhead contact conductors carrying current at high voltages, isolation must be such as to make even momentary contact impossible. Aside from placing the contact wires out of reach, protection is required to prevent other wires crossing above them from falling on the contact conductor or from being maliciously or accidentally tampered with from bridges or neighboring buildings.

Clearances

It has been found in extended experience that practical considerations determine the location of third rail conductors within very narrow limits. The location standardized by the American Railway Association is discussed in chapter 207. This location will not clear all existing permanent way structures nor all existing rolling stock; consequently, if the third rail is given such standard location, important changes must be made in the present railroad standards relating to structures and equipment. The changes required in permanent way structures resolve themselves into matters of cost; the changes required in rolling stock relate largely to special equipment such as wrecking derricks and snow plows. The adoption, therefore, of the third rail conductor will involve serious changes in existing structures and in existing work equipment.

TABLE CCXLVII. GAPS IN THIRD RAIL GREATER THAN 25 FEET
(Basis of 1912)

Railroad	Miles of Track in the Area of Investigation	No. of Gaps	Mileage of Gaps	Gaps and Suggested Remedy for Satisfactory Operation							
				Nothing Needed		Use Overhead		Rearrange Tracks		Shorten Gap	
				No.	Miles	No.	Miles	No.	Miles	No.	Miles
1	2	3	4	5	6	7	8	9	10	11	12
Chicago & North Western Ry	510.36	978	14.95	597	6.06	316	7.25	1	0.03	64	1.61
Illinois Central R. R	344.19	806	11.25	591	6.42	136	3.15	2	0.15	77	1.53
Chicago & Western Indiana R. R	307.57	854	13.75	335	3.66	100	2.15	7	0.41	412	7.53
Lake Shore & Michigan Southern Ry	180.88	399	3.67	211	2.27	51	1.06	..	..	137	0.34
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	134.22	406	6.32	188	2.37	88	1.65	9	0.20	121	2.10
Pittsburgh, Fort Wayne & Chicago Ry	177.78	391	6.48	294	3.28	46	0.97	20	1.68	31	0.55
Totals	1,655.00	3,834	56.42	2,216	24.06	737	16.23	39	2.47	842	13.66

At switches, at special or complicated track work, at highway crossings and at crossings of railroad tracks, the third rail cannot be made continuous but must be laid in sections connected by underground cables. Gaps are thus created in the contact system over which trains must coast. In certain locations coasting is not objectionable but in others, especially in yards and at switching points, turnouts and crossovers, no gaps can be allowed; consequently, where the third rail alongside the track must cease an overhead third rail conductor must be substituted. The character and location of this overhead third rail is described elsewhere (chapter 207). A detailed analysis of six important Chicago railroads, showing the extent to which resort to this form of construction would be necessary, is set forth by table CCXLVII.

It appears from table CCXLVII that, under present methods, the six railroads examined would have 3,834 gaps more than 25 feet in length in the third rail conductor, aggregating 56.42 miles. Of these gaps 2,216, aggregating 24.06 miles, would be unimportant since they would be short or would occur in places where trains could coast over them. Another class, numbering 881 gaps and aggregating 16.13 miles, could be reduced so that proper operation could be maintained; some of them could be eliminated by rearranging track or, assuming that permission could be obtained from the municipality, by closing some streets and reducing the width of other streets and roads. The expense of making these changes has not been determined, but it would be large. The remaining 737 gaps, averaging more than 115 feet in length and aggregating 16.23 miles, or about one per cent of the total mileage examined, would require the use of an overhead third rail conductor.

The list of gaps in third rail for the six railroads examined (table CCXLVII) does not include those on tracks on which electric operation could not be maintained owing to the fact that it is not possible to install third rail or overhead conductor rail. The extent of such track was determined for one railroad only and amounts to 11.65 miles.* Conditions on this road are representative. If it is assumed that the trackage of all railroads in the terminals which cannot be equipped with third rail bears the same ratio to the total as the mileage of track on the Chicago & North Western

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* The Chicago & North Western Railway.

Railway that cannot be equipped with third rail bears to the total terminal trackage of that road, it would appear that more than two per cent of the total mileage of track embraced by the Committee's studies, or about 75 miles, could not be equipped with third rail.

The construction of the overhead third rail is heavy and complicated. The supporting bridges increase complication and danger by interposing near the rails heavy structures which obstruct the view of tracks and signals. In yards the amount of such overhead construction required is extensive and costly and its presence introduces many difficulties in operation.

The presence of the third rail makes dangerous the crossing of yards and the coupling of cars. It makes more difficult the installation and operation of switches and signals. The view of signals on overhead signal bridges and of tracks would be more or less obstructed by the structures supporting the overhead conductor rail which would be required in many localities in the Chicago terminals.

The third rail as a mechanical obstruction involving hazard to the safety of men working in yards was considered in detail at a meeting of operating officials of Chicago railroads held under the auspices of the Committee.* It was agreed that it is necessary for employes to work on both sides of cars and that they would meet with the third rail obstruction everywhere. In repair yards the presence of the third rail would interfere with the work of men using jacks, bars and other tools. In other yards light repairs are sometimes made on cars in trains and the third rail would be an impediment to this work. The efficiency of inspectors and trainmen would be decreased owing to the danger of falling over the third rail. In some instances, where two third rail conductors must be located between tracks, very little space would remain in which a man could walk or run, as is required in switching operations.

These objections to the third rail pertain merely to the physical obstruction it imposes. Dangers arising from electric conditions attending its use are elsewhere considered (chapter 303).

Clearance is a matter of great importance in connection with a system of contact using high voltage overhead conductor wires. Not only must these wires be placed at a suitable height to permit the contact to be made from a moving train, but it is desirable that they be maintained at a height sufficient to clear trainmen on tops of cars while engaged in performing necessary duties. This protection should be such that trainmen cannot come in contact with the wires under any conditions. It requires not only that the wire shall be high enough to clear a tall man standing on top of the highest car but also high enough to permit him to give signals with a lantern swung overhead with outstretched arm. The recommended practice of the American Railway Association governing the limiting heights of overhead contact wires with high voltages is discussed elsewhere (chapter 207).

Overhead obstructions, such as highway or railroad bridges, present a difficult problem in connection with the installation of a workable overhead conductor. In general, where trainmen are permitted on tops of cars, the clearance under overhead bridges should not be less than 25 feet in order that the trolley wire may be 24 feet, 2 inches, above the top of rail. In cases where trainmen are barred from the tops of cars a minimum bridge clearance of 16 feet, 6 inches, is permissible.

An examination of clearances in the Chicago terminals reveals the fact that the installation of an overhead contact system of any kind cannot be made without important changes in existing structures above and near railroad tracks.

Within the Area of Investigation there are 492 permanent structures which fail to have sufficient clearance over tracks to allow the installation of the overhead conductor at the desired height of 24 feet, 2 inches. Of these obstructions, 221 cannot be changed without great inconvenience and expense both to the city and to the railroads. There are 385 structures which have clearances of less than 25 feet; 163 of these can be changed to provide the desired clearance, but not without material expense, and 222 cannot be changed without great inconvenience and expense. There are 70 of these structures which have less than the minimum clearance of 16 feet, 6 inches, permissible where trainmen are not permitted on tops of cars.

The conclusion follows that sufficient clearance

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*See Archives of the Committee, Vol. B 11 to permit employes to ride on tops of cars cannot be obtained throughout the Chicago terminals. It is necessary, therefore, to discuss the operating objections introduced by this fact.

Under present rules trainmen are required on tops of cars of road freight and transfer trains approaching stations and railroad crossings. A trainman is required on top of the head car of transfer trains when being pushed by locomotives. These rules are based upon procedures which are well established and are designed to secure safe and efficient operation.

Trainmen at present ride on tops of cars under certain conditions in classification yards. In flat yards it is occasionally necessary and in gravity yards it is generally necessary for trainmen to ride cars to set brakes. In gravity yards the whole scheme of operation is predicated upon having a man on each "cut" to operate the brakes.

In handling cars on team tracks, freight house tracks, industrial tracks and tracks in repair yards and storage yards, employes usually ride on tops of cars to give signals as guides in spotting cars and for the protection of workmen.

It is evident that under existing conditions trainmen at times ride on cars in nearly every class of work conducted on the tracks of the Chicago terminals. It is obvious, also, that if existing tracks were covered by an overhead contact system with frequent recurrence of low clearances, the present practice would need to be modified, for while riding on cars would be safe in certain localities, it could not be permitted in others.

At the meeting of the Chicago railroad officials previously referred to, the question of the practicability of excluding men from the tops of cars and of continuing the normal operation of the terminals was thoroughly discussed.* It was agreed that rules to be observed by trainmen could not both permit and prohibit riding on the tops of cars within the limits of the same terminal. It was the sense of this meeting that the exclusion of men from tops of cars would make impossible the operation of the Chicago terminals. If this view is accepted as final, it must be concluded that any form of overhead contact system is impracticable for general use in the terminals of Chicago.

The opinion thus expressed, while based upon an intimate knowledge of existing conditions, may not be wholly justified. It is always difficult to modify an established procedure and it is not easy to anticipate all that may be involved by such a change. However, the introduction of electric traction elsewhere has led to changes in operating conditions and, while there exist no precedents covering all of the conditions to be met in Chicago, it is reasonable to assume that a satisfactory procedure can be developed, though its consummation may involve inconvenience and added expense. There already exist within the Chicago terminals many localities in which, owing to physical obstructions, men cannot remain on tops of cars. In such cases warning devices are employed for protection. The introduction of an overhead electrical conductor would increase the danger to trainmen and it would increase the number of localities in which provision must be made for new forms of warning devices. With the protection afforded by such warnings it is believed that an extensive application of an overhead contact system will be found practicable for the Chicago terminals.

Reliability of Operation with the Different Contact Systems

Reliability of operation is an essential requirement of any technically feasible system of traction. Reliability of electric traction as a whole is discussed later (chapter 302). The present purpose is to consider conditions affecting the reliability of the contact systems.

Experience has shown that snow storms have no effect upon the catenary construction and current collecting equipment of the overhead contact systems. An ordinary snow storm does not materially interfere with operation with third rail, but drifting snows, such as often accompany storms in Chicago, cause considerable delay to traffic. The effect of snow on long lines of track or in very large yards is serious, because of the impracticability of using snow plows for the prompt removal of accumulations from the third rail.

Experience with the overhead contact system has shown that sleet formations on the contact wire cause some sparking but, except in the case of a most unusual storm, do not interfere with the movements of trains. The high voltage

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* Archives of the Committee, Vol. B 11.

employed on the overhead system and the flexibility of the construction are factors contributing to this result. With the third rail construction, however, sleet cannot be prevented from occasionally forming on the contact surface. When it does, it tends to insulate the collecting shoes of the locomotives or motor cars from the rail, making the operation of trains uncertain. It is the practice on several third rail roads to apply to the contact rail a chemical (chlorid of calcium) solution which softens the ice, and by following this with a scraper the surface of the rail may be cleaned. In severe sleet storms cars equipped to do this are operated continuously, a requirement which, especially in yards, is at times difficult to meet because of the presence of idle cars or trains.

With either the overhead construction or third rail, the failure of insulators and the grounding of the contact conductor or its feeders will cause an interruption in the supply of power to a track, and in some cases to an entire section. With all contact systems, interruptions of current on the contact may be confined by the switching stations to a relatively small extent of trackage. When failures are reported an emergency crew goes at once to the section affected. With the third rail contact system, the fact that the rail is located alongside the track makes it easily accessible for repairs. With the overhead contact, a defect in the conductor is less accessible and consequently more likely to require the presence of a repair train.

Derailments and wrecks where the third rail is employed may cause damage to the contact system. Short circuits may result and fire in wooden cars or combustible material may follow. Damage of this kind to the overhead contact system would not be likely to occur except in the case of a serious wreck.

In wrecking operations the overhead construction tends to interfere more or less with the freedom of work with cranes, but the fact that the wires are normally 25 feet above the track and that there is ample space between the contact wires tends materially to reduce the extent of this interference. It is assumed that current will be cut off from the overhead contact during wrecking operations. The third rail on tracks blocked by a wreck can hardly be said to constitute an obstruction, but its presence on adjoining tracks, if an attempt be made to maintain running conditions, is an obstruction to the free movement of the wrecking crew and equipment.

208.13 Rolling Equipment: The propulsion of trains in the terminals, in the event of electrification, would be secured by the use of electric locomotives for all freight service and for such passenger service as has its origin or destination outside of the limits of electrification, while local passenger trains would be composed of motor and trailer cars. The characteristics of electric locomotives and motor cars have been discussed elsewhere (chapter 207). It has been shown that, as regards capacity to perform any required work at the required operating speeds, they compare favorably with steam locomotives, and are thus suitable for work in the Chicago terminals. It has also been shown that, as regards reliability and safety, electric rolling equipment should be satisfactory for the terminal services. Technically, therefore, and aside from the question of permanency of type, the rolling equipment feature of an electric traction system may be definitely regarded as satisfactorily solved for the terminals.

208.14 Miscellaneous Equipment: In addition to the main elements of an electric traction system, hereinbefore discussed, there are certain facilities required to adapt the system as a whole to the terminal service. These are:

1. Electric locomotive houses.
2. Shops for the inspection and repair of rolling stock.
3. Transfer yards for the interchange of motive power on through runs.
4. Work and inspection equipment for repairs to line.
5. Telephones for intercommunication between all parts of the system.

All of these have been provided in other installations covering all the requirements of the Chicago terminals, and therefore their technical feasibility has been demonstrated.

The present signal systems used by 23 railroads in the Chicago terminals could not be used with any form of electric traction now available. Modifications in these signals will be necessary, such as the addition of new apparatus to harmonize with the changed conditions due to the presence of traction current in the track rails. It is technically feasible to make the changes required without affecting unfavorably the reliability of signals.*

208.15 The Return Circuit and Electrolysis: In all systems of traction under consideration, current is returned to the substations through the track rails and the earth. This current may also find its way through pipes, lead sheaths of cables and other metallic structures placed in the ground. As the losses in the return circuit are proportional to the resistance of the circuit, it is desirable to maintain reasonable conductivity. This is accomplished by bonding the rails at joints and installing return feeders and by cross-bonding rails. The factors which affect the public are more serious than the electrical loss in the return circuit; these factors are electrolysis and inductive interferences.

Direct current flowing from pipes and other metallic structures to the earth produces an electrolytic action at the point where the current leaves the metal. This action results in a disintegration of the metal which may eventually become serious. There has been a considerable amount of damage to water pipes, conduits, cables and similar property in all large cities through leakage of the return current from street railway lines, and it is possible that damage of this sort might be caused to property in Chicago by the installation of an extensive direct current traction system. No complete cure for this trouble has been found. The damage may be obviated to a great extent by installing return feeders, drainage connections and other devices. If, in addition, constant watchfulness is exercised the damage may become negligible, but the expense of such a procedure is considerable. With alternating current, on the other hand, there is practically no electrolytic action.

Various municipalities have framed ordinances to prevent damage from electrolysis in the electric operation of railroads, and Chicago has a very stringent ordinance for this purpose, passed by the City Council July 15, 1912. The following extracts show the character of the restrictions imposed by the ordinances.

> "SECTION 1. All uninsulated electrical return circuits must be of such current carrying capacity and so arranged that the difference of potential between any two points on the return will not exceed the maximum limit of twelve (12) volts, and between any two points on the return 1,000 feet apart within one mile radius of the City Hall will not exceed the limit of one (1) volt, and between any two points on the return 700 feet apart outside of this one mile radius limit will not exceed the limit of one (1) volt. In addition thereto, a proper return conductor system must be so installed and maintained as to protect all metallic work from electrolysis damage.
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> "The return current amperage on pipes and cable sheaths must not be greater than 0.5 amperes per pound foot for caulked cast iron pipe, 8 amperes per pound foot for screwed wrought iron pipe, and 16 amperes per pound foot for standard lead or lead alloy sheaths of cables."

This ruling was amended for the benefit of the Chicago surface railways in an ordinance dated November 13, 1913, extracts from which are as follows:

> "*A.* For the purpose of preventing damage by electrolysis the City of Chicago shall be divided into three (3) zones, as follows: The first, or inner zone, shall comprise that district of the city bounded by Lake Michigan on the east, 12th Street on the south, Halsted Street on the west and Chicago Avenue on the north. The second, or middle zone, shall comprise that district of the city lying outside of the inner zone, bounded as follows: Lake Michigan on the east, 79th Street on the south to Western Avenue; thence north along Western Avenue to 31st Street; thence west along 31st Street to 40th Avenue; thence north along 40th Avenue to Belmont Avenue; thence east along Belmont Avenue to Kedzie Avenue; thence north on Kedzie Avenue to Lawrence Avenue; thence east on Lawrence Avenue to Clark Street; thence north along Clark Street to city limits; thence east along the city limits to Lake Michigan; thence south along the shore of Lake Michigan to Chicago Avenue. The third, or outer zone, shall include all of the territory within the present or future limits of the City of Chicago not included in the inner and middle zones.
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> "*B.* All uninsulated electrical return circuits shall be of such current carrying capacity and so arranged that the sustained maximum difference of potential between any two points on any uninsulated portion of such circuit will not exceed the limit of ten (10) volts in the inner zone, fifteen (15) volts in the middle zone and twenty (20) volts in the outer zone; provided, however, that such sustained maximum difference of potential between any two such points in the grounded portion of the negative return shall not exceed a limit to be, from time to time, prescribed by the Board of Supervising Engineers; and provided, further, that the Board of Supervising Engineers shall have the power to increase the maximum drop in the outer zone to 25 volts at such points as may be deemed advisable by the Board for the extension of track into outlying dis-

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*A more detailed discussion of the changes necessary and the cost of changes will be found in chapter 213.

> tricts of the City where the underground utilities are not fully developed. The term 'sustained maximum difference of potential' is hereby defined as the highest average difference of potential for any 30-minute period during normal conditions of operation."

The evident purpose of the ordinances is to control the practice of the surface and elevated lines of the city. In the development of the traffic of the surface lines, however, it was found impracticable to meet the requirements of the first ordinance quoted, and its enforcement was waived until amended. Whether the ordinances will apply to steam railroads in the event of their electrification with a direct current system is, of course, not known. In many respects these provisions are hardly applicable to the conditions which would exist if the steam railroads were electrified. A comparison between the electrolysis caused by street railways and that caused by electrified steam railroads shows the following differences, all of which should be considered in any adjustment of the ordinances to make them applicable to electrified steam railroad conditions:

1. The tracks in the city streets are buried in the pavements and are therefore in close contact with the moisture in the streets; whereas the steam railroad tracks are laid in gravel, cinder or stone ballast on private rights-of-way; the ballast has provisions for drainage and therefore some insulating qualities.
2. The number and size of the sub-surface facilities which may be detrimentally affected by electrolysis are vastly greater in amount in city streets than under the railroad rights-of-way.
3. The pipes and cables laid alongside or under the railroad rights-of-way where they may be subject to electrolysis, are in a large part owned by the railroads themselves rather than by other interests as in the case of surface street facilities, and any damage which may be done by steam railroad electrification will therefore have its greatest effect upon property owned by the railroads.

In the Committee's further consideration of technical feasibility in its relation to electrolysis, it has been assumed that provision must be made for maintaining a low drop of potential in all tracks of the terminals, but the limits which have been accepted will not suffice to meet the requirements of the ordinance first quoted. The Committee's assumptions, however, provide for a maximum potential difference, considerably less than the requirements of the amended ordinance quoted, within the first zone specified. Within the middle and outer zones defined by the ordinance, the Committee's studies present one isolated case where the potential drop specified is exceeded, while outside of the city limits the potential drop will probably be largely in excess of that permitted by the city ordinance since these sections are in effect stub-end feeds from outermost substations. It must be remembered, however, that outside the city the lines pass through territory which is relatively sparsely populated and where possible damage from electrolysis may in most cases be regarded as negligible.

In the event of electrification with the 11,000-volt single-phase system, with which practically no electrolytic damage would occur, governing ordinances would require amendments to specify that they applied to direct current return circuits and not to all electric return circuits.

208.16 Inductive Interferences: The single-phase alternating current induces in neighboring wires and conductors, such as telephone and telegraph circuits, an electromotive force which, in the case of long lines close to the right-of-way, is sufficient to cause considerable disturbance and to prevent the proper working of the telephone and telegraph instruments. It has been the experience of the New York, New Haven & Hartford Railroad and of other railroads using single-phase alternating current that trunk lines of the telephone and telegraph companies have been disturbed; it has been necessary to place many of the lines underground and to re-route the long distance circuits so as to keep them out of the range of the traction system. A considerable sum of money has been spent in investigations to devise other means of preventing induction and much has been learned. However, the question of prevention of inductive effects has not been entirely solved and more effective methods must be developed. In Chicago, this question would be a serious one unless a satisfactory means were obtained whereby interference with the usefulness of telephone and telegraph circuits could be prevented.*

Meanwhile it may be assumed that the question of induction can be taken care of satisfactorily by

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*A detailed discussion of the procedures employed in the prevention of inductive disturbances is given in chapter 207.

carefully arranging feeding points, by providing a low resistance return circuit and by installing booster transformers. With such provisions the cabling of telephone and telegraph circuits will not be necessary.

208.17 A Summary of Facts and Conclusions concerning the Technical Feasibility of Electrification: The more important facts which have reference to the technical feasibility of electrification, as applied to the railroad terminals of Chicago, and the specific conclusions which seem justified by a review of these facts, may be set forth briefly as follows:

1. Through experience elsewhere it has been demonstrated that:
    a. Trains of any weight can be hauled electrically at any necessary speed, provided sufficient electric power can be conveyed to the traction motors.
    b. Where appliances can be properly installed and maintained, electric traction has been found to be reliable.
    c. The introduction of electric traction does not materially affect the hazard of railroad operation.
2. Electrification elsewhere has been undertaken in connection with different railroad services along the following lines:
    a. It has most frequently been employed in suburban passenger service.
    b. It has been used for all passenger services in connection with the intensive development of great passenger terminals where underground operation has been involved.
    c. It has been used for both freight and passenger operation in tunnels.
    d. It has been applied to sections of through lines to improve operation of both freight and passenger service on heavy grades.
    e. It has been applied to sections of through lines in anticipation of operating economies through the utilization of water power or other relatively inexpensive centralized power.
    f. It has been employed by a single railroad in this country in the operation of three switching yards, the work of which must still be regarded as being in an experimental stage.
3. An attempt to apply the demonstrated facts discloses the existence of a wide gap between that which has been accomplished and that which is necessary to meet all the various conditions presented by the proposed electrification of the Chicago terminals
4. Progress in the development of electric traction installations has thus far not resulted in the establishment of approved standards relating to equipment, transmission systems and methods of operation. The electrification of Chicago's terminals would, therefore, involve definite decisions with reference to fundamental questions of vital importance.
5. It is technically feasible for each individual road in Chicago, for any group of such roads, or for all such roads acting in common, to provide for the generation and distribution of power to predetermined points of consumption along the rights-of-way of railroads. The details of the methods by which this is to be accomplished constitute elements which will affect efficiency in installation and in the subsequent operation of the plant installed.
6. It is technically feasible for each individual road in Chicago, for any group of such roads, or for all such roads acting in common, to secure, through purchase, the energy they require, delivered at predetermined points of consumption along the rights-of-way.
7. Electrification implies the establishment of some form of contact system along each line of railroad track, whereby energy may be delivered to the rolling equipment. A study of track and operating conditions in the terminals reveals the following facts:
    a. A limited mileage of track in Chicago (from one to two per cent of the total) cannot be equipped with any system of contact which could be accepted as satisfactory for the terminals as a whole. The electrification of this trackage is, therefore, assumed to be not technically feasible.
    b. While the third rail system of contact might be extensively used in Chicago, there are, at intervals throughout a considerable portion of the total trackage, conditions which would make difficult the use of this form of contact.
    c. Any form of overhead contact which can be placed high enough to permit men to ride and perform their necessary duties on the tops of cars is not objectionable from a technical point of view. The application of any form of overhead contact system to the terminals of Chicago will, however, necessitate the lowering of the contact wire in many places in

order that it may pass under structures presenting less than the required clearance. In such locations provision will need to be made for the protection of trainmen, either through the agency of effective warning devices or the enforcement of rigid regulations relating to specific districts or localities.

8. The adoption of an overhead contact system will permit the use either of the so-called high voltage direct current or of alternating current at much higher voltage. The purposes of electrification can doubtless be accomplished through the adoption of either of these means.

9. The use of direct current by the railroads of Chicago would involve careful design and construction to avoid the introduction of difficulties arising from electrolytic action. While the questions of standards to be observed in this respect are as yet undetermined, it is believed that difficulties arising from this source are not such as to affect the feasibility of any general plan of electrification which may involve the use of direct current.

10. The use of alternating current by the railroads of Chicago would involve careful design and construction to avoid inductive interferences with existing telephone and telegraph circuits. While the means to be employed in preventing and overcoming such disturbances are not yet standardized, it is believed that the difficulties to be experienced from this source are not such as to affect the practicability of any general scheme of electrification involving the use of alternating current.

11. The general conclusion of the Committee regarding the technical feasibility of the complete electrification of Chicago's railroad terminals is to the effect that the execution of such an undertaking by the adoption of any known plan of electrification for use by all the different services of the city will introduce conditions which have not been covered by existing practice, but that, from an engineering point of view, none of these is to be regarded as insurmountable. The complete electrification of Chicago's railroad terminals is, therefore, to be regarded as technically feasible.

209. THE EXTENT OF THE PLAN UNDERLYING ESTIMATES OF THE COST OF ELECTRIFYING CHICAGO'S RAILROAD TERMINALS

SYNOPSIS: The plan presented by the Committee provides for the electric equipment and operation of all railroad tracks within the city of Chicago. In the case of several railroads, electrification is extended beyond the city limits. This chapter sets forth the more important considerations which have governed the Committee in fixing the limits of electric operation. The discussion is followed by a concise definition by roads of the extent of trackage involved by the plan, and by maps showing its location. The facts presented relate to the terminals and facilities of the railroads as they existed during the Committee's statistical year, 1912.

FACTORS CONSIDERED IN FIXING THE LIMITS OF ELECTRIFICATION

209.01 The Need of Defined Limits: Any estimate of the cost of equipping the railroad terminals of Chicago for electric operation, and of the expense of operation subsequent thereto, depends upon the extent of the plan of electrification. For reasons which will hereafter become apparent, the areas defined as Zones A and B, which have served in the Committee's study of smoke and atmospheric pollution (chapters 104 to 113), cannot be employed to advantage in defining the limits of electrification and no use is made of them in this connection. Instead of attempting to establish a zone of electrification, the extent of trackage to be dealt with has been fixed for each railroad. Points have been selected for the outer termini of electric operation with reference to certain general considerations inherent in the problem. The more important of these considerations are set forth in the sections which follow.

209.02 Complete Electrification within the City: It was early determined, as a principle to be recognized in fixing limits, that the plan of electrification should include all tracks within the corporate limits of the city of Chicago. The fact is not overlooked, however, that if electrification is resorted to as a means in smoke abatement, there are portions of the city in which its effect would be negligible. For example, the amount of smoke discharged by locomotives operating in the vicinity of South Chicago is of little consequence when compared with the enormous volumes of smoke discharged from the industrial fires in that vicinity. Again, there are stretches of territory within the corporate limits of the city which are at present unoccupied and from which objections to locomotive smoke are no more likely to arise than from rural portions of the state. In dealing with these and kindred facts, the Committee has interpreted its responsibility broadly. Its problem is a problem of the city of Chicago. The jurisdiction of the City Council extends over the entire territory of the city. In the event that electrification is required by action of the City Council, it would either initially or ultimately apply to all trackage within the city. An ordinance requiring electrification in portions of the city only would, if effective, probably be supplemented by other ordinances extending the requirement. Progress under an initial ordinance would in itself be construed as an argument favorable to an extension of the original limits, and in time the cost to the railroads would be that of equipping all tracks within the city limits. It has seemed proper, therefore, to accept complete electrification within the city limits of Chicago as an initial principle to be recognized in making up estimates of cost.

209.03 Extension of Complete Electrification beyond the City Limits: Assuming the electric operation of a railroad between its city terminus and the outer limits of the city to be necessary, the precise point at which electric operation should terminate still remains to be fixed. It cannot be assumed that the boundary of the city is in all cases a strategic point to be observed for such a purpose. A railroad having important suburban passenger service originating beyond the city limits, if required to electrify to the city limits, might for the greater convenience of its patrons be justified in continuing its scheme of electrification to some more distant point. Again, a railroad operating a small amount of trackage within the city might be justified, from an operating point of view, in increasing the length of its electrically operated section even though the added work might lie beyond the limits of the city.

Complete electrification within the city presupposes the removal to some point outside the city of all steam locomotive terminals, with their accessory facilities, such as coaling stations, water tanks and cinder pits, which are now maintained within the city. The facilities to be established outside the city for the care of steam locomotives, and the tracks necessary to accommodate trains while the motive power is being changed from steam to electric or from electric to steam, all involve the building of a considerable establishment. In the case of certain railroads, it has seemed impracticable to obtain space at the city limits in which to develop these necessary transfer facilities and, as a consequence, a more distant point has been accepted. The fact should be emphasized that extensions beyond the limits of the city, which are justified from these and similar considerations, are necessary, and their cost constitutes a legitimate charge to be included in the cost of equipment for electric terminal operation. It will be understood that complete electrification, as the term is herein used, implies the equipment of tracks of all kinds for electric operation and the exclusion of steam operation. The outer limits of complete electrification have, therefore, been fixed substantially upon the basis of the following considerations:

1. In the case of each railroad, it has been sought to terminate complete electrification at the first satisfactory point beyond the limits of the city.

2. In the case of railroads having large yards, repair shops or other facilities outside of the city and within a short distance therefrom, the location of such facilities has been accepted as a reasonable terminus for complete electrification.

3. In the case of railroads presenting no feature which might suggest a choice of location, a point has been selected, as near the city limits as practicable, which gives promise of supplying land upon which to develop the necessary terminal and transfer facilities.

209.04 Partial Electrification: In the case of several roads, it has seemed desirable to provide for partial electrification beyond the point where complete electrification terminates, in order that,

1. The establishment of transfer facilities may be permitted at a preferred point notwithstanding the fact that the point selected may be somewhat remote from the city; or,

2. Satisfactory provision may be made for important suburban passenger service.

Electrification in such cases is confined to main line tracks and to such other connected tracks as are normally involved in the operation of the main lines. No connecting yards are included. The purpose of partial electrification in these cases is to provide facilities which will handle traffic electrically from the boundary of the city to a satisfactory point of disposal. It is assumed that steam operated switching and transfer movements will be conducted over all such electrically equipped tracks. Sidings, other than passing sidings, and yards connected with these tracks will be steam operated.

Roads having heavy suburban business originating outside of the limits of the city would be placed at a disadvantage in the conduct of such business if required to stop each suburban train in its movement to and from the city for the purpose of changing from steam to electric power or from electric to steam power. In a few cases, therefore, where the traffic has been considered sufficient to justify it, the estimates provide for electrically operated multiple-unit service beyond the point of complete electrification. In all such cases, partial electrification implies the equipment only of tracks used for suburban service, and the movement over these tracks of electrically operated multiple-unit trains to some point at which a considerable number of trains normally terminate their runs.

209.05 Provisions for Multiple-Unit Service: It is assumed that all passenger service which is conducted wholly within the limits of electrification is to be performed by multiple-unit equipment, and provision for the care of such equipment is to be made accordingly. It is not contemplated that multiple-unit equipment will ordinarily be used in any other service. Passenger service which extends beyond the limits of electrification is to be performed by electric locomotives when inside the limits and by steam locomotives when outside. Under this principle, multiple-unit service is not reserved for conditions of congested traffic. It is assumed that roads having a light passenger business, if it lies wholly within the limits of electrification, will perform this service by the use of multiple-unit equipment.

In working out details under this general plan, multiple-unit equipment will be used by the following roads, within the limits defined:

Chicago & North Western Railway	Suburban service between the Madison Street Terminal and Waukegan; between the Madison Street Terminal and Desplaines; and between the Madison Street Terminal and Elmhurst.
Chicago & Western Indiana Railroad	For all passenger service.
Chicago, Burlington & Quincy Railroad	Suburban service between the Union Station and Downers Grove.
Chicago, Rock Island & Pacific Railway	Suburban service between the La Salle Street Station and Blue Island.
Illinois Central Railroad	Suburban service between the Randolph Street Station and Matteson, including also the South Chicago and Blue Island Branches.
Lake Shore & Michigan Southern Railway	Suburban service between the La Salle Street Station and Gary, including also the "loop" service via Indiana Harbor and Gibson.
Pittsburgh, Ft. Wayne & Chicago Railway	For suburban trains operating wholly within the limits of electrification.

209.06 Limits as Affected by Operating Conditions: Certain railroads operate trains into Chicago terminals over the tracks of other companies. Some of these have no trackage of their own in the city, though their locomotives, trains and train crews handle traffic within the city. The fact is recognized that, should electrification be required, such roads might effect arrangements under which their trains could be handled within the city limits by companies now affording them track facilities, and by so doing it would be possible for them to avoid the necessity of entering upon any scheme of electrification. In dealing with this aspect of the question, estimates are based upon the operating conditions which prevailed during the Committee's statistical year, 1912. It is assumed that a road which, during that year, was operating trains into a Chicago terminal under a trackage agreement with another road, will provide for a continuance of such operation even though it be required to do so electrically. In the case of such roads, therefore, the estimates provide for the cost of the electric locomotives necessary to secure the movement of their trains within the city, and the cost of such transfer and terminal facilities outside the city as will be required for changing from steam to electric motive power.

209.07 Industrial Tracks: The trackage included in the plan of electrification embraces not only the tracks of railroad companies but also a considerable mileage of standard gage industrial tracks not owned by railroad companies. This is classified as "adjacent industrial track privately owned." Difficulty has been experienced in obtaining plans or other information necessary to an accurate determination of the amount of track owned by certain industries, and in such cases the amount has been estimated. There are some tracks which are so located and operated as to make electrification by any form of contact system difficult and perhaps impracticable. The extent of tracks coming under this classification is relatively small and the amount is not included in the track to be electrified (section 209.10).

209.08 Factors Governing the Location of Transfer and Shop Facilities: The location of terminal facilities and the selection of points at which steam and electric locomotives and multiple-unit cars are to be inspected and repaired, necessarily predetermine certain movements incident to the subsequent operation of the road possessing them. The selection of a location for any such facility is therefore a matter of far-reaching importance. Some of the factors to be considered in making a selection are sufficiently general in their application to be accepted as principles which apply to conditions prevailing upon all roads, while others are in the nature of expediencies and, as such, are peculiar to an individual road. In recognition of these facts, careful and painstaking attention has been given in locating all such facilities and the general principles have, so far as they are known, been applied. It is not to be assumed, however, that action has been based upon a perfect knowledge of a problem which relates to a prospective practice, and which, in the case of many roads, is as yet unstudied by those who must ultimately be responsible for its correct solution. It is believed that the general scheme with reference to the location of such facilities, as defined by the descriptive sections which follow, will be found practicable and that as a basis for an estimate of cost it will not prove misleading.

In dealing with existing terminal and shop facilities, it has been assumed that all terminal facilities for the care of steam locomotives within the city are to be removed; that such facilities outside the city, even though located on lines which are to be electrified, are to be retained; and that existing repair shops within the city for the care of steam locomotives are generally to be retained and rearranged for use in repairing electric equipment.

209.09 General Considerations: In dealing with the various questions which have arisen in the process of determining the limits to be observed in the development of electric operation, an effort has been made to secure a just balance between two conflicting points of view. On the one hand, the committee has carefully guarded against the danger of overloading the estimates through the adoption of a plan more extensive than necessary. On the other hand, care has been taken to make the plan sufficiently comprehensive to render the estimates which are based thereon of fullest practical value in setting forth the cost incident to equipping and operating electrically the railroad terminals of Chicago.

209.10 Trackage and Terminal Facilities: Application of the principles set forth in the preceding sections has resulted in a plan providing for the electrification of existing trackage as follows:

	MILES	
Route embraced by complete electrification .	450.20	
Route embraced by partial electrification . .	115.00	
Total route		565.20
Main track	1,475.59	
Other track	1,733.83	
Adjacent industrial track, privately owned .	229.72	
Total electrically equipped track . . .		3,439.14

The trackage accredited to each of the several roads within the limits of electrification as defined is shown by table CCXLVIII.

TABLE CCXLVIII. TRACKAGE TO BE ELECTRIFIED ON EACH RAILROAD IN THE CHICAGO TERMINALS

(Basis of 1912)

Railroad 1	Miles of Main Track 2	Miles of Other Track 3	Adjacent Industrial Track Privately Owned 4	Total Miles of Track to be Electrically Equipped 5
Atchison, Topeka & Santa Fe Ry	28.92	52.98	6.05	87.95
Baltimore & Ohio R. R.	32.55	25.79	1.13	59.47
Baltimore & Ohio Chicago Terminal R. R.	66.23	39.65	8.53	114.41
Calumet, Hammond & Southeastern R. R.	....	5.90	......	5.90
Chesapeake & Ohio Ry. of Indiana	....	0.18	......	0.18
Chicago & Alton R. R.	20.07	36.24	2.61	58.92
Chicago & Calumet River R. R.	....	3.16	17.86	21.02
Chicago & Eastern Illinois R. R.	2.30	19.18	1.18	22.66
Chicago & Erie R. R.	5.41	28.54	0.29	34.24
Chicago & North Western Ry	263.64	258.71	9.83	532.18
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	141.39	162.53	15.00	318.92
Chicago, Burlington & Quincy R. R	81.54	86.04	17.56	185.14
Chicago Great Western R. R.	0.68	19.87	0.04	20.59
Chicago, Indiana & Southern R. R.	9.39	2.39	......	11.78
Chicago, Indianapolis & Louisville Ry	3.98	1.66	......	5.64
Chicago Junction Ry	44.59	118.98	34.90	198.47
Chicago, Milwaukee & St. Paul Ry	106.83	136.82	17.19	260.84
Chicago River & Indiana R. R.	5.54	0.95	3.89	10.38
Chicago, Rock Island & Pacific Ry	76.88	62.00	......	138.88
Chicago Short Line Ry.	....	0.59	4.71	5.30
Chicago Union Transfer Ry	5.61	2.36	0.15	8.12
Chicago, West Pullman & Southern R. R.	....	2.86	15.02	17.88
Elgin, Joliet & Eastern Ry	6.07	104.46	2.71	113.24
Grand Trunk Western Ry	21.64	36.65	6.07	64.36
Illinois Central R. R.	168.94	163.89	4.18	337.01
Illinois Northern Ry	4.36	7.24	9.29	20.89
Indiana Harbor Belt R. R.	22.77	0.60	......	23.37
Lake Shore & Michigan Southern Ry	98.86	63.60	0.99	163.45
Michigan Central R. R.	22.96	43.89	1.37	68.22
Minneapolis, St. Paul & Sault Ste. Marie Ry	0	0	0	0
New York, Chicago & St. Louis R. R	30.64	27.42	......	58.06
Pere Marquette R. R.	....	9.70	......	9.70
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	62.05	68.74	5.35	136.14
Pittsburgh, Fort Wayne & Chicago Ry	113.96	81.48	13.31	208.75
Pullman R. R.	6.97	8.62	30.01	45.60
Wabash R. R.	20.82	50.16	0.50	71.48
Totals	1,475.59	1,733.83	229.72	3,439.14

The provisions of the plan for electrification of the Chicago railroad terminals involve the establishment of new facilities and changes in existing facilities as follows:

Transfer yards to be established	30
Establishments to be provided for the care of electric equipment	50
New establishments to be provided for the care of steam equipment	25
Existing establishments for the care of steam equipment to be enlarged	5
Establishments for the care of steam equipment to be abandoned or removed to new locations	39

The extent of the plan providing for electric operation over existing trackage is shown by the accompanying map, fig. 543.

EXTENT OF THE PLAN OF ELECTRIFICATION, BY RAILROADS

209.11 Limits of Electrification Defined for Each Railroad: The extent of the plan of electrification of the Chicago railroad terminals upon which estimates of cost are based, as defined for each road, is presented in the following paragraphs.

Atchison, Topeka & Santa Fe Railway
(1912)

Estimates provide for electric operation of trunk line passenger service over the tracks of the Chicago & Western Indiana Railroad from Dearborn Station to Chicago & Western Indiana Junction (20th and Grove streets), 1.3 miles; thence for all services over company tracks to a point near McCook, Ill., 13.4 miles from Dearborn Station. A transfer yard and facilities for the care of steam and electric locomotives are to be established a short distance west of McCook. Within the limits defined, all tracks, including those in the Corwith Yard, are to be equipped for electric operation.

The use of existing facilities for the care of steam locomotives within the city, particularly at the 18th Street Yard and at the Corwith Yard, is to be discontinued, and any machinery which is available for removal is to be transferred to McCook.

The foregoing provisions involve existing trackage of the Atchison, Topeka & Santa Fe Railway, as follows:

	MILES	
Route embraced by complete electrification	12.10	
Route embraced by partial electrification	0.00	
Total route		12.10
Main track	28.92	
Other track	52.98	
Adjacent industrial track, privately owned	6.05	
Total electrically equipped track		87.95

This statement does not include the trackage of the proposed transfer yard to be established at McCook (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Atchison, Topeka & Santa Fe Railway is shown by the accompanying map, fig. 544.

Baltimore & Ohio Railroad
(1912)

Estimates provide for electric operation of trunk line service over the tracks of the Baltimore & Ohio Chicago Terminal Railroad from Grand Central Station to Baltimore & Ohio Junction, 11.2 miles; thence over the tracks of the Baltimore & Ohio Connecting Railroad (Baltimore & Ohio) to Brainerd Junction, 2.1 miles; thence over the tracks of the Chicago, Rock Island & Pacific Railway to Rock Island Junction; thence over Baltimore & Ohio Railroad tracks to Pine Junction, Ind., 29.3 miles from Grand Central Station; and also for electric operation of passenger service from Brookdale (70th Street and Dorchester Avenue) to Rock Island Junction, 4.1 miles. For all Baltimore & Ohio Railroad tracks within the city, complete electrification is to be provided, while for tracks from the city limits to Pine Junction main line electrification only is contemplated. A transfer yard and facilities for the care of steam and electric locomotives are to be established a short distance east of Pine Junction, Ind.

The use of existing facilities for the care of steam locomotives at the South Chicago yard is to be discontinued, and any machinery which is available for removal is to be transferred to the proposed transfer yard to be established at Pine Junction.

The foregoing provisions involve existing trackage of the Baltimore & Ohio Railroad to the extent shown in the following:

FIG. 543. TRACKAGE TO BE ELECTRIFIED IN THE CHICAGO RAILROAD TERMINALS

FIG. 544. TRACKAGE TO BE ELECTRIFIED BY THE ATCHISON, TOPEKA & SANTA FE RAILWAY

	MILES	
Route embraced by complete electrification	8.10	
Route embraced by partial electrification	8.20	
Total route		16.30
Main track	32.55	
Other track	25.79	
Adjacent industrial track, privately owned	1.13	
Total electrically equipped track		59.47

This statement does not include the trackage of the proposed transfer yard to be established at Pine Junction (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Baltimore & Ohio Railroad is shown by the accompanying map, fig. 545.

Baltimore & Ohio Chicago Terminal Railroad (1912)

Estimates provide for electric operation from the Grand Central Station to Forest Park, Ill., 10.9 miles; from Western Avenue Junction to a point near Barr, Ill., 16.9 miles; and for the operated portion of the branch from 48th Avenue and Taylor Street to 16th Street and Harlem Avenue, 1.9 miles. Estimates provide also for main line electrification for the operation of Wabash and Pennsylvania trains from Chicago & Western Indiana Junction near the Illinois-Indiana State Line east to Pine Junction, Ind., 6.1 miles, the Baltimore & Ohio Chicago Terminal Railroad to maintain steam operation over this section. A transfer yard and facilities for the care of steam and electric equipment are to be established at Barr.

The use of existing facilities for the care of steam locomotives within the city is to be discontinued and any machinery which is available for removal is to be transferred to Barr. At the Robey Street Yard, facilities are to be provided for the care of electric locomotives. Existing facilities for the care of steam locomotives at the East Chicago Yard are to be retained.

The foregoing provisions involve existing trackage of the Baltimore & Ohio Chicago Terminal Railroad as follows:

	MILES	
Route embraced by complete electrification	29.40	
Route embraced by partial electrification	6.10	
Total route		35.50
Main track	66.23	
Other track	39.65	
Adjacent industrial track, privately owned	8.53	
Total electrically equipped track		114.41

This statement does not include the trackage of the proposed transfer yard to be established at Barr (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Baltimore & Ohio Chicago Terminal Railroad is shown by the accompanying map, fig. 546.

Calumet, Hammond & Southeastern Railroad (1912)

The tracks of this railroad lie wholly within the city limits of Chicago. Estimates provide for its complete electrification.

The use of existing facilities for the care of steam locomotives is to be discontinued and facilities for the care of electric equipment are to be provided.

The foregoing provisions involve existing trackage of the Calumet, Hammond & Southeastern Railroad as follows:

	MILES	
Route embraced by complete electrification	0.00	
Route embraced by partial electrification	0.00	
Total route		0.00
Main track	0.00	
Other track	5.90	
Adjacent industrial track, privately owned	0.00	
Total electrically equipped track		5.90

The extent of the plan providing for electric operation over existing trackage of the Calumet, Hammond & Southeastern Railroad is shown by the accompanying map, fig. 547.

Chesapeake & Ohio Railway of Indiana (1912)

Estimates provide for electric operation of trunk line service over the tracks of the Chicago & Western Indiana Railroad from Dearborn Station to the Illinois-Indiana State Line, 19.8 miles; thence over the tracks of the Chicago & Erie Railroad to HY Tower, 22.5 miles from Dearborn Station, this point marking the beginning of the tracks of the Chesapeake & Ohio Railway of Indiana.

The Chesapeake & Ohio Railway of Indiana is to use facilities for the care of electric equipment to be provided by the Chicago & Western Indiana Railroad at its 51st Street Yard. At the HY Tower Yard the present facilities for the care of

FIG. 545. TRACKAGE TO BE ELECTRIFIED BY THE BALTIMORE & OHIO RAILROAD

FIG. 546. TRACKAGE TO BE ELECTRIFIED BY THE BALTIMORE & OHIO CHICAGO TERMINAL RAILROAD

FIG. 547. TRACKAGE TO BE ELECTRIFIED BY THE CALUMET, HAMMOND & SOUTHEASTERN RAILROAD

FIG. 548. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO & ALTON RAILROAD

steam locomotives are to be enlarged and facilities for the care of electric equipment are to be added. A transfer yard is also to be established at this point.

The foregoing provisions involve existing trackage of the Chesapeake & Ohio Railway of Indiana as follows:

	MILES	
Route embraced by complete electrification	0.00	
Route embraced by partial electrification	0.00	
Total route		0.00
Main track	0.00	
Other track	0.18	
Adjacent industrial track, privately owned	0.00	
Total electrically equipped track		0.18

This statement does not include the trackage of the proposed transfer yard to be established at HY Tower (section 213.095).

Chicago & Alton Railroad
(*1912*)

Estimates provide for electric operation of trunk line service over tracks owned jointly by the Chicago & Alton Railroad and the Pittsburgh, Ft. Wayne & Chicago Railway from the Union Station to Fort Wayne Junction, 1.8 miles; thence over company tracks to Glenn, Ill., 10.0 miles from the Union Station. A transfer yard and limited facilities for the care of electric equipment are to be established at Glenn.

The use of existing facilities for the care of steam locomotives at the Brighton Park Yard is to be discontinued and any machinery which is available for removal is to be transferred to Glenn. At Brighton Park and Glenn, facilities for the care of electric locomotives are to be provided.

The foregoing provisions involve existing trackage of the Chicago & Alton Railroad as follows:

	MILES	
Route embraced by complete electrification	10.00	
Route embraced by partial electrification	0.00	
Total route		10.00
Main track	20.07	
Other track	36.24	
Adjacent industrial track, privately owned	2.61	
Total electrically equipped track		58.92

This statement does not include the trackage of the proposed facilities to be established at Glenn (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Chicago & Alton Railroad is shown by the accompanying map, fig. 548.

Chicago & Calumet River Railroad
(*1912*)

The tracks of this railroad lie wholly within the city limits of Chicago. Estimates provide for its complete electrification.

The use of existing facilities for the care of steam locomotives is to be discontinued, and facilities for the care of electric equipment are to be provided.

The foregoing provisions involve existing trackage of the Chicago & Calumet River Railroad as follows:

	MILES	
Route embraced by complete electrification	0.00	
Route embraced by partial electrification	0.00	
Total route		0.00
Main track	0.00	
Other track	3.16	
Adjacent industrial track, privately owned	17.86	
Total electrically equipped track		21.02

The extent of the plan providing for electric operation over existing trackage of the Chicago & Calumet River Railroad is shown by the accompanying map, fig. 549.

Chicago & Eastern Illinois Railroad
(*1912*)

Estimates provide for electric operation of trunk line service over the tracks of the Chicago, Rock Island & Pacific Railway from the La Salle Street Station to Auburn Park, 8.6 miles; thence over tracks of the Chicago & Western Indiana Railroad to a point near Dolton Junction, 16.9 miles from the La Salle Street Station; thence over company tracks to Yard Center, 18.3 miles from the La Salle Street Station. Sidings within the city owned by this company are to be electrified. From the limits of the Chicago & Western Indiana Railroad tracks at Dolton Junction to Yard Center, main tracks only are to be electrified. A transfer yard and facilities for the care of steam and electric locomotives are to be provided at Yard Center.

The Chicago & Eastern Illinois Railroad is to use facilities for the care of electric equipment which are to be provided by the Chicago & Western Indiana Railroad at its 51st Street Yard.

The foregoing provisions involve existing trackage of the Chicago & Eastern Illinois Railroad as follows:

	MILES	
Route embraced by complete electrification	0.00	
Route embraced by partial electrification	1.30	
Total route		1.30
Main track	2.30	
Other track	19.18	
Adjacent industrial track, privately owned	1.18	
Total electrically equipped track		22.66

This statement does not include the trackage of the proposed transfer yard to be established at Yard Center (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Chicago & Eastern Illinois Railroad is shown by the accompanying map, fig. 550.

Chicago & Erie Railroad
(1912)

Estimates provide for electric operation of trunk line service over the tracks of the Chicago & Western Indiana Railroad from Dearborn Station to the Illinois-Indiana State Line, 19.8 miles; thence over company tracks to Hammond, Ind., 20.8 miles from Dearborn Station. From the Illinois-Indiana State Line to Hammond, main tracks only are to be electrified. From Hammond to HY Tower, 22.5 miles from Dearborn Station, the main tracks of the Chicago & Erie Railroad are to be electrified for the operation of trains of the Chesapeake & Ohio Railway of Indiana. A transfer yard and facilities for the care of steam and electric locomotives are to be established at Hammond.

The Chicago & Erie Railroad is to use facilities for the care of electric equipment to be provided by the Chicago & Western Indiana Railroad at its 51st Street Yard.

The foregoing provisions involve existing trackage of the Chicago & Erie Railroad as follows:

	MILES	
Route embraced by complete electrification	0.00	
Route embraced by partial electrification	2.70	
Total route		2.70
Main track	5.41	
Other track	28.54	
Adjacent industrial track, privately owned	0.29	
Total electrically equipped track		34.24

This statement does not include the trackage of the proposed transfer yard to be established at Hammond (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Chicago & Erie Railroad is shown by the accompanying map, fig. 551.

Chicago & Illinois Western Railroad
(1912)

This road lies entirely outside the city limits of Chicago. Estimates do not provide for the electrification of any of its tracks. It is assumed that under electrification a few trains which it now operates within the city will be handled by one of its connecting roads.

Chicago & North Western Railway
(1912)

Estimates provide for complete electric operation of trunk line and suburban service from the Madison Street Terminal to Waukegan, Ill., 36.2 miles; from the Passenger Terminal to Desplaines, Ill., 16.7 miles; from 40th Avenue to Canal Junction, Evanston, 13.6 miles; from River Junction to Niles Center, 3.3 miles; from the Passenger Terminal to Oak Park, Ill., 8.6 miles, with main line electrification beyond to Elmhurst, Ill., 15.9 miles from the Terminal. Estimates also provide for complete electric operation of the Rockwell Street and the 16th Street lines, 4.5 miles. A transfer yard and facilities for the care of electric locomotives and multiple-unit trains are to be established at Waukegan and the present facilities at this point for the care of steam locomotives are to be enlarged. A transfer yard and facilities for the care of steam and electric locomotives are to be established a short distance west of Park Ridge and also at a point a short distance south of Niles Center. Facilities are to be provided at Proviso for the care of electric locomotives and the present facilities at this point for the care of steam locomotives are to be

FIG. 549. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO & CALUMET RIVER RAILROAD

FIG. 550. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO & EASTERN ILLINOIS RAILROAD

FIG. 551. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO & ERIE RAILROAD

FIG. 552. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO & NORTH WESTERN RAILWAY

enlarged. Tracks for the care of multiple-unit trains are to be provided at Elmhurst.

The use of existing facilities for the care of steam locomotives at the Wood Street Yard, at the 40th Avenue Yard, at the Chicago Avenue Yard, and at Weber is to be discontinued, and any machinery which is available for removal is to be transferred to the proposed transfer yards to be established at Waukegan, Park Ridge, Niles Center and Proviso. The 40th Avenue shops are to be retained and such facilities added as may be required for the care of electric equipment. At the Chicago Avenue Yard, and at the 40th Avenue Yard facilities for the inspection and repair of multiple-unit equipment are to be installed.

The foregoing provisions involve existing trackage of the Chicago & North Western Railway as follows:

	MILES	
Route embraced by complete electrification	84.40	
Route embraced by partial electrification	7.30	
Total route		91.70
Main track	263.64	
Other track	258.71	
Adjacent industrial track, privately owned	9.83	
Total electrically equipped track		532.18

This statement does not include the trackage of the proposed transfer yards to be established at Waukegan, Park Ridge, Niles Center and Proviso (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Chicago & North Western Railway is shown by the accompanying map, fig. 552.

Chicago & Western Indiana Railroad and the Belt Railway of Chicago
(1912)

Estimates provide for complete electric equipment of all tracks of these companies, including those leased or used by tenant lines. The routes of the Chicago & Western Indiana Railroad extend from Dearborn Station to Auburn Junction, 8.0 miles; from Pullman Junction to the Illinois-Indiana State Line, 7.6 miles; and from Hammond Junction to Dolton Junction, 7.5 miles. The routes of the Belt Railway of Chicago extend from Auburn Junction to Cragin, Ill., 15.9 miles; from Pullman Junction to South Chicago, 2.7 miles; and from Rock Island Junction to South Deering, 2.7 miles. The tracks which occupy the route from Auburn Junction to Pullman Junction, 4.2 miles, are jointly operated. It is provided that all passenger service operated by the Chicago & Western Indiana Railroad is to be performed by multiple-unit equipment. No transfer yards are to be provided.

The statistics of traffic and operation of these companies have been reported to the Committee jointly and not segregated for the two roads. There has therefore been no segregation in the estimates of cost.

The use of existing facilities for the care of steam locomotives at the 83d Street Yard and at the 51st Street Yard is to be discontinued and complete facilities for the care of electric equipment are to be provided.

The foregoing provisions involve existing trackage of the Chicago & Western Indiana Railroad and the Belt Railway of Chicago as follows:

	MILES	
Route embraced by complete electrification	48.60	
Route embraced by partial electrification	0.00	
Total route		48.60
Main track	141.39	
Other track	162.53	
Adjacent industrial track, privately owned	15.00	
Total electrically equipped track		318.92

The extent of the plan providing for electric operation over existing trackage of the Chicago & Western Indiana Railroad and the Belt Railway of Chicago is shown by the accompanying map, fig. 553.

Chicago, Burlington & Quincy Railroad
(1912)

Estimates provide for electric operation of trunk line service and of multiple-unit service over tracks owned jointly by the Chicago & Alton Railroad and the Pittsburgh, Fort Wayne & Chicago Railway, from the Union Station to 16th and Canal streets, 1.4 miles; thence over company tracks to Hawthorne, Ill., 6.8 miles from Union Station. From Hawthorne to Downers Grove, Ill., 21.3 miles from Union Station, electrification of tracks is to be provided for the operation of multiple-unit trains. Complete electrification is to be provided for all tracks in the "Lumber District." A transfer yard and facilities for the care of steam locomotives are to be established at the Hawthorne Yard.

The use of existing facilities for the care of steam locomotives at the 12th Street Yard and at the Western Avenue Yard is to be discontinued and provision is to be made at the Western Avenue Yard for the care of electric equipment. Machinery now used for the care of steam locomotives at the Western Avenue Yard, if available for removal, is to be transferred to the proposed transfer yard at Hawthorne.

The foregoing provisions involve existing trackage of the Chicago, Burlington & Quincy Railroad as follows:

	MILES	
Route embraced by complete electrification	5.40	
Route embraced by partial electrification	14.50	
Total route		19.90
Main track	81.54	
Other track	86.04	
Adjacent industrial track, privately owned	17.56	
Total electrically equipped track		185.14

This statement does not include the trackage of the proposed transfer yard to be established at Hawthorne (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Chicago, Burlington & Quincy Railroad is shown by the accompanying map, fig. 554.

Chicago Great Western Railroad

(1912)

Estimates provide for electric operation of trunk line passenger service over the tracks of the Baltimore & Ohio Chicago Terminal Railroad from Grand Central Station to Forest Park, Ill., 10.6 miles. Transfer tracks are to be established at Forest Park. The 48th Avenue Yard, comprising all the trackage owned by this company within the city limits of Chicago, is to be completely electrified. Facilities for the care of steam locomotives are to be established at Bellwood, Ill., 13.2 miles from Grand Central Station.

The use of the existing facilities for the care of steam locomotives at the 48th Avenue Yard is to be discontinued and any machinery which is available for removal is to be transferred to Bellwood. Facilities for the care of electric locomotives are to be established at the 48th Avenue Yard.

The foregoing provisions involve existing trackage of the Chicago Great Western Railroad as follows:

	MILES	
Route embraced by complete electrification	0.00	
Route embraced by partial electrification	0.34	
Total route		0.34
Main track	0.68	
Other track	19.87	
Adjacent industrial track, privately owned	0.04	
Total electrically equipped track		20.59

This statement does not include the proposed transfer tracks to be established at Forest Park (section 213.095).

Chicago, Indiana & Southern Railroad

(1912)

Estimates provide for electric operation of trunk line service over the tracks of the Lake Shore & Michigan Southern Railway from La Salle Street Station to Indiana Harbor, Ind., 19.3 miles; thence over company tracks to Osborn, Ind., 24.1 miles from the La Salle Street Station. From Indiana Harbor to Osborn, 4.8 miles, main tracks only are to be electrified, principally for the operation of Lake Shore & Michigan Southern Railway suburban trains. Facilities for the care of electric locomotives are to be provided at the Gibson Yard, and those of the Lake Shore & Michigan Southern Railway to be provided at Englewood are also to be used by this road.

The foregoing provisions involve existing trackage of the Chicago, Indiana & Southern Railroad as follows:

	MILES	
Route embraced by complete electrification	0.00	
Route embraced by partial electrification	4.80	
Total route		4.80
Main track	9.39	
Other track	2.39	
Adjacent industrial track, privately owned	0.00	
Total electrically equipped track		11.78

This statement does not include any proposed trackage which may be electrified in connection with the establishment of facilities for the care of electric equipment at the Gibson Yard (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Chicago, Indiana & Southern Railroad is shown by the accompanying map, fig. 555.

FIG. 553. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO & WESTERN INDIANA RAILROAD AND THE BELT RAILWAY OF CHICAGO

FIG. 554. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO, BURLINGTON & QUINCY RAILROAD

Chicago, Indianapolis & Louisville Railway (*1912*)

Estimates provide for electric operation of trunk line service over the tracks of the Chicago & Western Indiana Railroad from Dearborn Station to the Illinois-Indiana State Line, 19.8 miles; thence over company tracks having main line electrification only, to South Hammond, Ind., 23.3 miles from Dearborn Station. A transfer yard and facilities for the care of electric locomotives are to be provided at South Hammond, and the present facilities at this point for the care of steam locomotives are to be enlarged.

The Chicago, Indianapolis & Louisville Railway is to use facilities for the care of electric equipment which are to be provided by the Chicago & Western Indiana Railroad at its 51st Street Yard.

The foregoing provisions involve existing trackage of the Chicago, Indianapolis & Louisville Railway as follows:

	MILES	
Route embraced by complete electrification	0.00	
Route embraced by partial electrification	3.50	
Total route		3.50
Main track	3.98	
Other track	1.66	
Adjacent industrial track, privately owned	0.00	
Total electrically equipped track		5.64

This statement does not include the trackage of the proposed transfer yard to be established at South Hammond (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Chicago, Indianapolis & Louisville Railway is shown by the accompanying map, fig. 556.

Chicago Junction Railway (*1912*)

The tracks of this railroad lie wholly within the limits of Chicago. Estimates provide for its complete electrification. Its main tracks extend from a connection with the Illinois Central Railroad at 41st Street westward to a point near Western Avenue, thence northward to Ogden Avenue, 8.8 miles.

The use of existing facilities for the care of steam locomotives at the Ashland Avenue Yard is to be discontinued and facilities for the care of electric equipment are to be provided.

The foregoing provisions involve existing trackage of the Chicago Junction Railway as follows:

	MILES	
Route embraced by complete electrification	11.80	
Route embraced by partial electrification	0.00	
Total route		11.80
Main track	44.59	
Other track	118.98	
Adjacent industrial track, privately owned	34.90	
Total electrically equipped track		198.47

The extent of the plan providing for electric operation over existing trackage of the Chicago Junction Railway is shown by the accompanying map, fig. 557.

Chicago, Milwaukee & St. Paul Railway (*1912*)

Estimates provide for electric operation of trunk line service from the Union Station over tracks owned jointly by the Chicago, Milwaukee & St. Paul Railway and the Pittsburgh, Cincinnati, Chicago & St. Louis Railway to Western Avenue, 3.0 miles; thence over company tracks to Morton Grove, Ill., 14.8 miles from Union Station; from Union Station over jointly owned tracks, as above, to Western Avenue; thence over company tracks to Mannheim, Ill., 14.5 miles from Union Station; from Union Station to Wilmette, Ill., 14.1 miles; from Chicago and Evanston Junction (Clybourn and Racine avenues) west along Bloomingdale Avenue to Pacific Junction, 3.3 miles; and from Galewood to Dunning, Ill., 3.0 miles. Transfer yards and facilities for the care of steam and electric equipment are to be established at Morton Grove and at Mannheim and the existing facilities at the latter point for the care of steam locomotives are to be enlarged. Multiple-unit trains of the Northwestern Elevated Railroad Company at present use the tracks of the Chicago, Milwaukee & St. Paul Railway from Argyle Street to Wilmette; these tracks are equipped with a 600-volt overhead contact system.

The use of existing facilities for the care of steam locomotives at the Western Avenue Yard and at the Galewood Yard is to be discontinued, and any machinery at these points available for removal is to be transferred to the proposed transfer yards at Morton Grove and Mannheim. Shop facilities at the Western Avenue Yard are

FIG. 555. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO, INDIANA & SOUTHERN RAILROAD

FIG. 556. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO, INDIANAPOLIS & LOUISVILLE RAILWAY

FIG. 557. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO JUNCTION RAILWAY

FIG. 558. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

FIG. 559. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO RIVER & INDIANA RAILROAD

to be retained and such facilities added as may be required for the care of electric equipment.

The foregoing provisions involve existing trackage of the Chicago, Milwaukee & St. Paul Railway as follows:

	MILES	
Route embraced by complete electrification	46.20	
Route embraced by partial electrification	0.00	
Total route		46.20
Main track	106.83	
Other track	136.82	
Adjacent industrial track, privately owned	17.19	
Total electrically equipped track		260.84

This statement does not include the trackage of the proposed transfer yards to be established at Morton Grove and Mannheim (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Chicago, Milwaukee & St. Paul Railway is shown by the accompanying map, fig. 558.

Chicago River & Indiana Railroad
(1912)

The trackage of this railroad lies wholly within the city limits of Chicago. Estimates provide for its complete electrification.

The Chicago River & Indiana Railroad is to use facilities for the care of electric equipment which are to be provided by the Chicago Junction Railway at its Ashland Avenue Yard.

The foregoing provisions involve existing trackage of the Chicago River & Indiana Railroad as follows:

	MILES	
Route embraced by complete electrification	1.10	
Route embraced by partial electrification	0.00	
Total route		1.10
Main track	5.54	
Other track	0.95	
Adjacent industrial track, privately owned	3.89	
Total electrically equipped track		10.38

The extent of the plan providing for electric operation over existing trackage of the Chicago River & Indiana Railroad is shown by the accompanying map, fig. 559.

Chicago, Rock Island & Pacific Railway
(1912)

Estimates provide for electric operation of trunk line and multiple-unit service from La Salle Street Station to Blue Island, Ill., 15.9 miles; from Gresham to Blue Island (Suburban Line), 6.5 miles; and from Gresham Junction to South Chicago, 5.8 miles. Transfer tracks and facilities for the care of electric locomotives and multiple-unit cars are to be established at the Burr Oak Yard, near Blue Island, and the present facilities at this point for the care of steam equipment are to be enlarged.

The use of existing facilities for the care of steam locomotives at the 47th Street Yard is to be discontinued and any machinery at this point available for removal is to be transferred to the proposed transfer yard at Burr Oak. Facilities for the care of electric locomotives are to be provided at the 47th Street Yard, and the present shop facilities at this point are to be adapted to that purpose.

The foregoing provisions involve existing trackage of the Chicago, Rock Island & Pacific Railway as follows:

	MILES	
Route embraced by complete electrification	28.20	
Route embraced by partial electrification	1.70	
Total route		29.90
Main track	76.88	
Other track	62.00	
Adjacent industrial track, privately owned	0.00	
Total electrically equipped track		138.88

This statement does not include the proposed transfer tracks to be established at Burr Oak (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Chicago, Rock Island & Pacific Railway is shown by the accompanying map, fig. 560.

Chicago Short Line Railway
(1912)

The trackage of this railroad lies wholly within the city limits of Chicago. Estimates provide for its complete electrification.

The use of existing facilities for the care of steam locomotives at 97th Street and Avenue N is to be discontinued and facilities for the care of electric equipment are to be provided at this point.

The foregoing provisions involve existing trackage of the Chicago Short Line Railway as follows:

FIG. 560. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO, ROCK ISLAND & PACIFIC RAILWAY

FIG. 561. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO SHORT LINE RAILWAY

FIG. 562. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO UNION TRANSFER RAILWAY

	MILES	
Route embraced by complete electrification	0.00	
Route embraced by partial electrification	0.00	
Total route		0.00
Main track	0.00	
Other track	0.59	
Adjacent industrial track, privately owned	4.71	
Total electrically equipped track		5.30

The extent of the plan providing for electric operation over existing trackage of the Chicago Short Line Railway is shown by the accompanying map, fig. 561.

*Chicago Union Transfer Railway**
(*1912*)

The business of this railroad is confined to freight traffic. Estimates provide for complete electrification from Elsdon to the Chicago city limits at 69th Street and Cicero Avenue, 3.5 miles. A transfer yard and facilities for the care of electric locomotives are to be provided at 69th Street and Cicero Avenue. The existing facilities at the same point for the care of steam equipment are to be retained.

The foregoing provisions involve existing trackage of the Chicago Union Transfer Railway as follows:

	MILES	
Route embraced by complete electrification	3.50	
Route embraced by partial electrification	0.00	
Total route		3.50
Main track	5.61	
Other track	2.36	
Adjacent industrial track, privately owned	0.15	
Total electrically equipped track		8.12

This statement does not include the trackage of the proposed transfer yard to be established at 69th Street and Cicero Avenue (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Chicago Union Transfer Railway is shown by the accompanying map, fig. 562.

Chicago, West Pullman & Southern Railroad
(*1912*)

The tracks of this railroad lie wholly within the city limits of Chicago. Estimates provide for its complete electrification.

The use of existing facilities for the care of steam locomotives at West Pullman and at South Deering is to be discontinued and facilities for the care of electric equipment are to be provided.

The foregoing provisions involve existing trackage of the Chicago, West Pullman & Southern Railroad as follows:

	MILES	
Route embraced by complete electrification	0.00	
Route embraced by partial electrification	0.00	
Total route		0.00
Main track	0.00	
Other track	2.86	
Adjacent industrial track, privately owned	15.02	
Total electrically equipped track		17.88

The extent of the plan providing for electric operation over existing trackage of the Chicago, West Pullman & Southern Railroad is shown by the accompanying map, fig. 563.

Elgin, Joliet & Eastern Railway
(*1912*)

Estimates provide for electric operation of all service within the city limits of Chicago. All tracks within the city, including those at the South Works of the Illinois Steel Company, those from the South Works to the eastern city limits, those at the North Works of the Illinois Steel Company, those at the Bridgeport Yard and those at the South Chicago Yard, are to be completely electrified. Transfer tracks are to be established at a point near the intersection of the lines of this railroad with the eastern city limits.

The use of existing facilities for the care of steam locomotives at 86th Street and Buffalo Avenue, at the South Chicago Yard and at the North Works Yard is to be discontinued and facilities for the care of electric equipment are to be provided at these points.

The foregoing provisions involve existing trackage of the Elgin, Joliet & Eastern Railway as follows:

	MILES	
Route embraced by complete electrification	2.80	
Route embraced by partial electrification	0.00	
Total route		2.80
Main track	6.07	
Other track	104.46	
Adjacent industrial track, privately owned	2.71	
Total electrically equipped track		113.24

This statement does not include the proposed

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*The Chicago Union Transfer Railway was acquired by the Belt Railway of Chicago during the Committee's statistical year, 1912.

FIG. 563. TRACKAGE TO BE ELECTRIFIED BY THE CHICAGO, WEST PULLMAN & SOUTHERN RAILROAD

transfer tracks to be established at a point near the eastern city limits (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Elgin, Joliet & Eastern Railway is shown by the accompanying map, fig. 564.

Grand Trunk Western Railway
(1912)

Estimates provide for electric operation of trunk line service over the tracks of the Chicago & Western Indiana Railroad from Dearborn Station to Chicago & Western Indiana Junction (49th and Butler streets), 4.9 miles; thence over company tracks to a point near Evergreen Park, Ill., 15.3 miles from Dearborn Station. Within the above limits all tracks are to be electrified. A transfer yard and facilities for the care of steam and electric equipment are to be provided at a point a short distance south of Evergreen Park.

The use of existing facilities for the care of steam locomotives at the Elsdon Yard is to be discontinued and any machinery available for removal is to be transferred to the proposed transfer yard at Evergreen Park.

The foregoing provisions involve existing trackage of the Grand Trunk Western Railway as follows:

	MILES	
Route embraced by complete electrification	10.40	
Route embraced by partial electrification	0.00	
Total route		10.40
Main track	21.64	
Other track	36.65	
Adjacent industrial track, privately owned	6.07	
Total electrically equipped track		64.36

This statement does not include the trackage of the proposed transfer yard to be established at Evergreen Park (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Grand Trunk Western Railway is shown by the accompanying map, fig. 565.

Illinois Central Railroad
(1912)

Estimates provide for electric operation of all service from Randolph Street to Central Station, 1.4 miles; from Central Station to Harvey, Ill., 18.6 miles (all tracks within these limits except sidings at Riverdale and Harvey to be electrified), thence, with main line electrification for the operation of multiple-unit service only, to Matteson, Ill., 28.8 miles from Central Station; and electric operation of the South Chicago Branch from Brookdale to South Chicago, 4.7 miles. The estimates also provide for electric operation of the Blue Island Branch, 4.1 miles; and for electric operation from Central Station to Hawthorne, Ill. (except for yard tracks at Hawthorne), 7.9 miles. Transfer yards and facilities for the care of steam and electric equipment are to be provided at Hawthorne and Harvey.

The use of existing facilities for the care of steam locomotives, principally at 27th Street and at Burnside, is to be discontinued and any machinery which is available for removal is to be transferred to the proposed transfer yards at Hawthorne and at Harvey. At Burnside the present shop facilities for the care of existing equipment are to be retained and additions are to be made for the care of electric locomotives and multiple-unit equipment.

The foregoing provisions involve existing trackage of the Illinois Central Railroad as shown in the following:

	MILES	
Route embraced by complete electrification	33.5	
Route embraced by partial electrification	13.7	
Total route		47.2
Main track	168.94	
Other track	163.89	
Adjacent industrial track, privately owned	4.18	
Total electrically equipped track		337.01

The above statement does not include the trackage of the proposed transfer yards to be established at Hawthorne and at Harvey (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Illinois Central Railroad is shown by the accompanying map, fig. 566.

Illinois Northern Railway
(1912)

The tracks of this railroad lie wholly within the city limits of Chicago. Estimates provide for its complete electrification.

The use of existing facilities for the care of steam locomotives at McCormick (26th Street and Western Avenue) is to be discontinued and

FIG. 564. TRACKAGE TO BE ELECTRIFIED BY THE ELGIN, JOLIET & EASTERN RAILWAY

FIG. 565. TRACKAGE TO BE ELECTRIFIED BY THE GRAND TRUNK WESTERN RAILWAY

FIG. 566. TRACKAGE TO BE ELECTRIFIED BY THE ILLINOIS CENTRAL RAILROAD

facilities for the care of electric locomotives are to be provided at this point.

The foregoing provisions involve existing trackage of the Illinois Northern Railway as follows:

	MILES	
Route embraced by complete electrification	3.50	
Route embraced by partial electrification	0.00	
Total route		3.50
Main track	4.36	
Other track	7.24	
Adjacent industrial track, privately owned	9.29	
Total electrically equipped track		20.89

The extent of the plan providing for electric operation over existing trackage of the Illinois Northern Railway is shown by the accompanying map, fig. 567.

Indiana Harbor Belt Railroad
(1912)

Estimates provide for electric operation of freight service from the Union Stock Yards to Chappell, Ill., 9.9 miles, tracks within the city to be completely electrified and those from the city limits to Chappell to have main line electrification only.

A transfer yard and facilities for the care of electric locomotives are to be established at Chappell and the present facilities at this point for the care of steam locomotives are to be retained.

The foregoing provisions involve existing trackage of the Indiana Harbor Belt Railroad as follows:

	MILES	
Route embraced by complete electrification	5.30	
Route embraced by partial electrification	4.60	
Total route		9.90
Main track	22.77	
Other track	0.60	
Adjacent industrial track, privately owned	0.00	
Total electrically equipped track		23.37

This statement does not include the trackage of the proposed transfer yard to be established at Chappell (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Indiana Harbor Belt Railroad is shown by the accompanying map, fig. 568.

Lake Shore & Michigan Southern Railway
(1912)

Estimates provide for electric operation of trunk line and multiple-unit service from the La Salle Street Station over company tracks to Millers, Ind., 30.1 miles, the tracks within the city limits to be completely electrified and those from the eastern city limits to Millers to have main line electrification only. A transfer yard and facilities for the care of steam and electric equipment including multiple-unit trains are to be established at Millers.

The use of existing facilities for the care of steam locomotives at the Englewood Yard is to be discontinued and any machinery available for removal is to be transferred for use at the proposed yard at Millers. At Englewood the present shop facilities are to be retained and additions are to be made to provide for the care of electric equipment. The Englewood shops are also to provide for repairs to the electric locomotives of the Chicago, Indiana & Southern Railroad.

The foregoing provisions involve existing trackage of the Lake Shore & Michigan Southern Railway as follows:

	MILES	
Route embraced by complete electrification	14.30	
Route embraced by partial electrification	15.80	
Total route		30.10
Main track	98.86	
Other track	63.60	
Adjacent industrial track, privately owned	0.99	
Total electrically equipped track		163.45

This statement does not include the trackage of the proposed transfer yard to be established at Millers (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Lake Shore & Michigan Southern Railway is shown by the accompanying map, fig. 569.

Manufacturers' Junction Railway
(1912)

The tracks of this railroad lie wholly outside of the city limits of Chicago and no electrification is proposed. It is assumed that traffic which is now handled by the Manufacturers' Junction Railway within the city will, under electrification, be handled by its connecting railroads. The business of this road within the city is limited.

FIG. 567. TRACKAGE TO BE ELECTRIFIED BY THE ILLINOIS NORTHERN RAILWAY

FIG. 568. TRACKAGE TO BE ELECTRIFIED BY THE INDIANA HARBOR BELT RAILROAD

FIG. 569. TRACKAGE TO BE ELECTRIFIED BY THE LAKE SHORE & MICHIGAN SOUTHERN RAILWAY

Michigan Central Railroad *(1912)*

Estimates provide for electric operation of trunk line service over the tracks of the Illinois Central Railroad from the South Water Street Yard to Kensington, Ill., 14.5 miles, thence over company tracks to Gibson, Ind., 23.8 miles from Central Station. All company tracks within the city limits of Chicago, including the South Water Street Yard, are to be completely electrified and those from the city limits to Gibson are to be equipped for electric operation of the main tracks only. A transfer yard and facilities for the care of steam and electric locomotives are to be established at a point a short distance east of Gibson.

The use of existing facilities for the care of steam locomotives at 16th Street and at the Kensington Yard is to be discontinued and any machinery available for removal is to be transferred to the proposed transfer yard at Gibson. Limited facilities for the care of electric locomotives are to be provided at Kensington.

The foregoing provisions involve existing trackage of the Michigan Central Railroad as follows:

	MILES	
Route embraced by complete electrification	3.80	
Route embraced by partial electrification	7.60	
Total route		11.40
Main track	22.96	
Other track	43.89	
Adjacent industrial track, privately owned	1.37	
Total electrically equipped track		68.22

This statement does not include the trackage of the proposed transfer yard to be established at Gibson (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Michigan Central Railroad is shown by the accompanying map, fig. 570.

Minneapolis, St. Paul & Sault Ste. Marie Railway (1912)

Estimates provide for electric operation of trunk line service over the tracks of the Illinois Central Railroad from Central Station to Hawthorne, Ill., 8.0 miles, the transfer and terminal facilities of the Illinois Central Railroad at this point to be used. As the Minneapolis, St. Paul & Sault Ste. Marie Railway owns no trackage within the city limits of Chicago, no estimates are made for electrification of its tracks but estimates provide for its electric power supply and rolling equipment.

New York, Chicago & St. Louis Railroad *(1912)*

Estimates provide for electric operation of trunk line service over the tracks of the Chicago, Rock Island & Pacific Railway from La Salle Street Station to Rock Island Junction (Pullman Junction), 11.4 miles, thence over company tracks to Hessville, Ind., 23.7 miles from La Salle Street Station, and from Pullman Junction to Grand Crossing, 2.2 miles. The tracks within the city limits of Chicago are to be completely electrified and those from the city limits to Hessville are to have main track electrification only. A transfer yard and facilities for the care of steam and electric locomotives are to be provided at a point a short distance east of Hessville.

The use of existing facilities for the care of steam locomotives at the Stony Island Yard is to be discontinued and any machinery which is available for removal is to be transferred to the proposed yard at Hessville. At the Stony Island Yard present shop facilities are to be retained and additions are to be made to provide for the care of electric locomotives.

The foregoing provisions involve existing trackage of the New York, Chicago & St. Louis Railroad as follows:

	MILES	
Route embraced by complete electrification	8.0	
Route embraced by partial electrification	5.7	
Total route		13.7
Main track	30.64	
Other track	27.42	
Adjacent industrial track, privately owned	0.00	
Total electrically equipped track		58.06

This statement does not include the trackage of the proposed transfer yard to be established at Hessville (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the New York, Chicago & St. Louis Railroad is shown by the accompanying map, fig. 571.

Pere Marquette Railroad (1912)

Estimates provide for electric operation of trunk line passenger service over the tracks of the Baltimore & Ohio Chicago Terminal Railroad from

FIG. 570. TRACKAGE TO BE ELECTRIFIED BY THE MICHIGAN CENTRAL RAILROAD

FIG. 571. TRACKAGE TO BE ELECTRIFIED BY THE NEW YORK, CHICAGO & ST. LOUIS RAILROAD

Grand Central Station to Ft. Wayne Junction, 1.1 miles, thence over tracks of the Pittsburgh, Ft. Wayne & Chicago Railway to Clarke Junction, Ind., 22.1 miles from Grand Central Station, and for electric operation of freight service over the tracks of the Baltimore & Ohio Chicago Terminal Railroad from Chicago to Barr, Ind., 20.3 miles. Transfer yards and facilities for the care of steam and electric locomotives are to be established at Clarke Junction and at Barr.

The use of the existing facilities for the care of steam locomotives at the Tracy Yard and at the Empire Slip Yard of the Baltimore & Ohio Chicago Terminal Railroad is to be discontinued and any machinery which is available for removal is to be transferred to the proposed yards at Barr and at Clarke Junction.

The foregoing provisions involve existing trackage of the Pere Marquette Railroad as follows:

	MILES	
Route embraced by complete electrification	0.00	
Route embraced by partial electrification	0.00	
Total route		0.00
Main track	0.00	
Other track	9.70	
Adjacent industrial track, privately owned	0.00	
Total electrically equipped track		9.70

This statement does not include the trackage of the proposed transfer yards to be established at Barr and Clarke Junction (section 213.095).

Pittsburgh, Cincinnati, Chicago & St. Louis Railway (1912)

Estimates provide for electric operation of trunk line service over tracks owned jointly by the Pittsburgh, Cincinnati, Chicago & St. Louis Railway and the Chicago, Milwaukee & St. Paul Railway from the Union Station to Western Avenue, 3.0 miles; thence over company tracks to Bernice, Ill., 26.9 miles from Union Station. The Englewood Connecting Railway is to be completely electrified. A transfer yard and facilities for the care of steam and electric locomotives are to be established at a point a short distance east of Bernice.

The use of existing facilities for the care of steam locomotives at the Curtis Street Yard and at the 59th Street Yard is to be discontinued, and any machinery which is available for removal is to be transferred for use at the proposed yard at Bernice. Facilities for the care of electric locomotives are to be provided at the 59th Street Yard.

The foregoing provisions involve existing trackage of the Pittsburgh, Cincinnati, Chicago & St. Louis Railway as follows:

	MILES	
Route embraced by complete electrification	28.90	
Route embraced by partial electrification	0.00	
Total route		28.90
Main track	62.05	
Other track	68.74	
Adjacent industrial track, privately owned	5.35	
Total electrically equipped track		136.14

This statement does not include the trackage of the proposed transfer yard to be established at Bernice (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Pittsburgh, Cincinnati, Chicago & St. Louis Railway is shown by the accompanying map, fig. 572.

Pittsburgh, Ft. Wayne & Chicago Railway (1912)

Estimates provide for the electric operation of trunk line service over tracks owned jointly by the Pittsburgh, Ft. Wayne & Chicago Railway and the Chicago & Alton Railroad from the Union Station to Ft. Wayne Junction, 1.8 miles; thence over company tracks to Clarke, Ind., 24.5 miles from Union Station. All tracks within the city limits are to be completely electrified and those from the city limits to Clarke are to have main line electrification only. A transfer yard and facilities for the care of steam and electric locomotives are to be established at a point a short distance north of Clarke.

Estimates provide also for the complete electrification of the Pennsylvania branches from Bernice to Colehour, 9.3 miles; from Hegewisch to River Branch Junction, 4.4 miles; from Rock Island Junction to Hegewisch, 5.0 miles; and from Hegewisch to the city limits, 1.3 miles; and for main line electrification only from the city limits to Pine Junction, 7.1 miles, and from Hammond to the Illinois-Indiana State Line, 0.9 mile.

The use of existing facilities for the care of steam locomotives at the 14th Street Yard and at the Garfield Boulevard Yard is to be discontinued and any machinery which is available for

FIG. 572. TRACKAGE TO BE ELECTRIFIED BY THE PENNSYLVANIA LINES (PITTSBURGH, CINCINNATI, CHICAGO & ST. LOUIS RAILWAY AND PITTSBURGH, FORT WAYNE & CHICAGO RAILWAY)

FIG. 573. TRACKAGE TO BE ELECTRIFIED BY THE PULLMAN RAILROAD

FIG. 574. TRACKAGE TO BE ELECTRIFIED BY THE WABASH RAILROAD

removal is to be transferred to the proposed yard at Clarke. At the Garfield Boulevard Yard the present shop facilities are to be retained and additions are to be made to provide for the care of electric equipment.

The foregoing provisions involve existing trackage of the Pittsburgh, Ft. Wayne & Chicago Railway as follows:

	MILES	
Route embraced by complete electrification .	34.90	
Route embraced by partial electrification .	17.60	
Total route		52.50
Main track	113.96	
Other track	81.48	
Adjacent industrial track, privately owned .	13.31	
Total electrically equipped track. . .		208.75

This statement does not include the trackage of the proposed transfer yard to be established at Clarke (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Pittsburgh, Ft. Wayne & Chicago Railway is shown by the accompanying map, fig. 572.

Pullman Railroad (1912)

The tracks of this railroad lie wholly within the city of Chicago. The estimates provide for their complete electrification.

The use of facilities for the care of steam locomotives is to be discontinued and facilities for the care of electric equipment are to be provided.

The foregoing provisions involve existing trackage of the Pullman Railroad as follows:

	MILES	
Route embraced by complete electrification .	6.50	
Route embraced by partial electrification .	0.00	
Total route		6.50
Main track	6.97	
Other track	8.62	
Adjacent industrial track, privately owned .	30.01	
Total electrically equipped track . .		45.60

The extent of the plan providing for electric operation over existing trackage of the Pullman Railroad is shown by the accompanying map, fig. 573.

Wabash Railroad (1912)

Estimates provide for the electric operation of trunk line service over the tracks of the Chicago & Western Indiana Railroad from Dearborn Station to Western Indiana Junction, 8.0 miles; thence over company tracks to Chicago Ridge, Ill., 16.9 miles from Dearborn Station. Electric operation of trunk line passenger service is also to be conducted over the tracks of the Chicago & Western Indiana Railroad from Dearborn Station to the Illinois-Indiana State Line, 19.8 miles; thence over tracks of the Baltimore & Ohio Chicago Terminal Railroad to Clarke Junction, Ind., 26.0 miles from Dearborn Station. All tracks owned by the Wabash Railroad within the city limits, including those in the Ullman Street Yard, are to be electrified. Transfer yards and facilities for the care of steam and electric locomotives are to be established near Chicago Ridge and near Clarke Junction.

The use of existing facilities for the care of steam locomotives at the Landers Yard and the 51st Street Yard of the Chicago & Western Indiana Railroad is to be discontinued and any machinery available for removal is to be transferred for use at the proposed yards at Chicago Ridge and Clarke Junction. The Wabash Railroad is to use facilities for the care of electric equipment which are to be provided by the Chicago & Western Indiana Railroad at its 51st Street Yard.

The foregoing provisions involve existing trackage of the Wabash Railroad as follows:

	MILES	
Route embraced by complete electrification .	8.90	
Route embraced by partial electrification .	0.50	
Total route		9.40
Main track	20.82	
Other track	50.16	
Adjacent industrial track, privately owned .	0.50	
Total electrically equipped track . .		71.48

This statement does not include the trackage of the proposed transfer yards to be established at Chicago Ridge and at Clarke Junction (section 213.095).

The extent of the plan providing for electric operation over existing trackage of the Wabash Railroad is shown by the accompanying map, fig. 574.

210. SYSTEMS SELECTED AS A BASIS FOR ESTIMATES OF COST

SYNOPSIS: This chapter presents a discussion of the factors influencing the Committee's selection of electric traction systems upon which to base estimates of cost, and gives a brief description of each of the three systems selected for this purpose.

210.01 Difficulties Attendant upon the Selection of a System of Electric Traction: As yet no system of electric traction has been developed which can be accepted as standard for all conditions on all railroads. If it were decided to proceed at once with the electrification of the Chicago terminals, it would be difficult for any group of men to choose a system which would not be criticized by other men as able as those upon whom the choice of the system devolved. Arguments would be advanced in favor of each of the several systems available. There are many factors affecting the choice of a system, some of which are based upon known technical facts and others of which are the outgrowth of local conditions.

The system selected for Chicago must be suitable not only for passenger terminals and main line work but also for yard switching and transfer work. It must be applicable to the requirements of railroads having a heavy suburban traffic and also to those of roads conducting freight yard and switching service. It must not only be satisfactory in its application to the terminal portion of a trunk line railroad, but it must lend itself to an indefinite extension of the limits of electrification over other and adjoining portions of the road. It is furthermore essential, because of the varied activities of the terminal, that the rolling equipment of the system selected shall be capable of operating over the tracks of all railroads in the electrified zone.

In the development of the electrification of the Chicago terminals, the very extent of the work requires that the system of traction selected shall possess certain characteristics of permanency. Obviously, the project must be regarded as too important to permit of the introduction of methods in any way questionable, or of a type of construction of untried value. Furthermore, it is not permissible to consider any methods which might serve to tide over a temporary condition anticipating the later selection of a permanent and stable system. It cannot be said that the details of any system are entirely predetermined, since electrifications thus far installed vary greatly not only in fundamental characteristics but in details.

210.02 Systems Selected as a Basis for the Committee's Estimates of Cost: The types of electric traction systems now in use in America and in foreign countries have already been described (chapter 207). If electrification were to be entered upon, it would be necessary to select some one of these types and to proceed with its installation. But no one system will perfectly meet the requirements of the Chicago terminals, and the art is constantly developing. The purpose of the Committee is to determine the cost rather than to settle details of construction, and to supply a basis for as broad a perspective as can readily be secured. In the accomplishment of these purposes, estimates of the cost have been prepared separately for three different systems of traction of recognized merit, as follows:

1. Third rail contact, direct current at 600 volts.
2. Overhead contact, direct current at 2,400 volts.
3. Overhead contact, single-phase current at 11,000 volts.

The estimates for the two overhead contact systems have been developed for all railroads within the proposed limits of electrification. Estimates for the third rail system have been developed for a single road, and the cost determined in this manner has been extended to cover the entire terminal.

The Committee's action in this matter designedly postpones the selection of the one system which must ultimately be chosen as best suited to the needs of the Chicago situation, until the actual work of equipping the terminal becomes imminent.

211. ENERGY REQUIREMENTS

SYNOPSIS: The volume and flow of traffic within the proposed limits of electrification have already been discussed (chapter 202). The present chapter shows the amount of energy required to handle this traffic electrically. The values thus obtained underlie estimates of the amount of electric equipment required and estimates of the expense which will be involved by the operation of the Chicago terminals subsequent to electrification.

211.01 Traffic to be Handled under the Proposed Plan of Electrification: A knowledge of the amount of electric energy which will be required to operate the Chicago railroad terminals is essential in the development of the plans of the power station, transmission system and substations, and in the preparation of estimates of their cost. The determination of the amount of energy required has been based upon a knowledge of the total volume of traffic to be handled within the proposed limits of electrification. The results of a comprehensive study of the extent of the traffic and of the character and frequency of train movements for all roads within the entire Area of Investigation, as defined in chapter 103, are presented in chapter 202.

The total traffic, as measured by ton-miles, in all classes of service for the average day of the five periods for which reports were made, is 4.7 per cent less than that for the average day of the October report period. Since the October report is the most accurate and is the only one for which hourly studies were made, it has served as the basis for all energy determinations; that is, the average day of the October report period has been accepted as fairly representing the average day for the year. Since the trackage to be electrified under the proposed plan of electrification does not coincide with the trackage within the Area of Investigation or within either of the two zones and since the weight of the proposed electric trains will not be the same as that of the present steam trains, it has been necessary to correct the total traffic values presented in chapter 202 in order to show the volume of traffic which will be handled within the limits of electrification by the various railroads involved. In cases in which the proposed limits of electric operation for a road fall within the limits of the Area of Investigation, the traffic values were easily determined from the statistical record in which train movements are recorded by route elements, or short sections of track. In cases in which the proposed limits of electric operation extend beyond the limits of the Area of Investigation, the extent of the traffic beyond the limits was determined, for passenger service, by laying out train sheets from the time-tables and, for freight service, by assuming that all traffic which passes beyond the limits of the Area of Investigation will proceed to the point which marks the proposed limits of electric operation.

After making corrections for the difference between the track mileage within the Area of Investigation and that within the limits of electrification, and for the difference between the weight of the present steam equipment and that of the proposed electric equipment, the statistical record given in chapter 202 was used as a basis on which to determine the number of ton-miles of traffic to be handled hourly during the average October day in each class of service. These determinations were made upon the basis of the assumed use, first, of an overhead contact system of electrification employing direct current at 2,400 volts, and second, of an overhead contact system of electrification employing alternating current at 11,000 volts.

Methods employed in determining costs of a third rail system of electrification are hereinafter set forth. Diagrams showing the extent of the traffic, by services and by systems, are presented as figs. 575 to 589, inclusive.

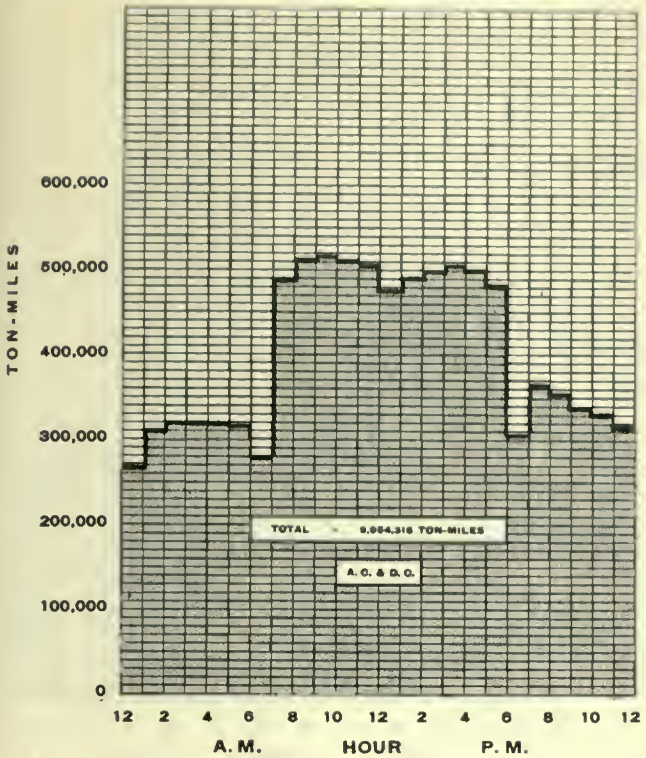

FIG. 575. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Yard Service, both A. C. and D. C. Operation.

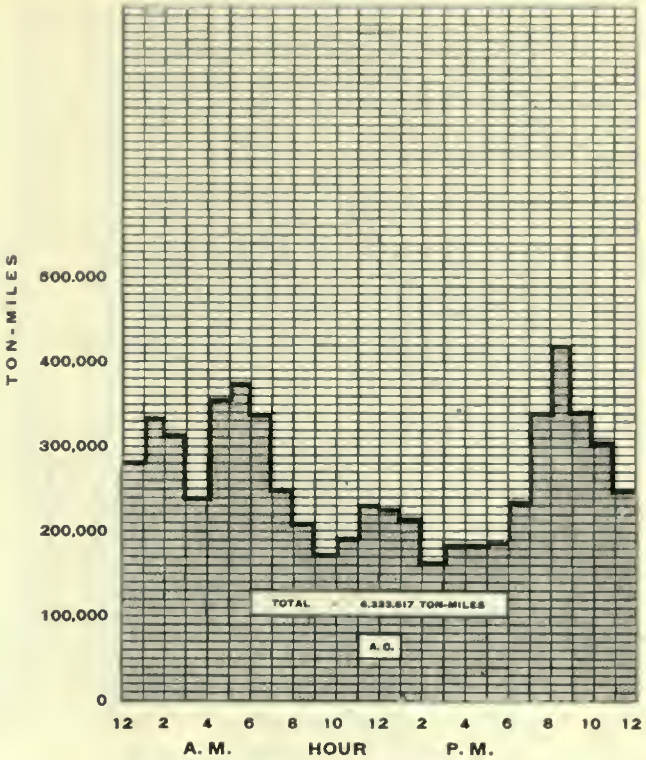

FIG. 577. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Road Freight Service, 11,000-Volt A. C. Operation.

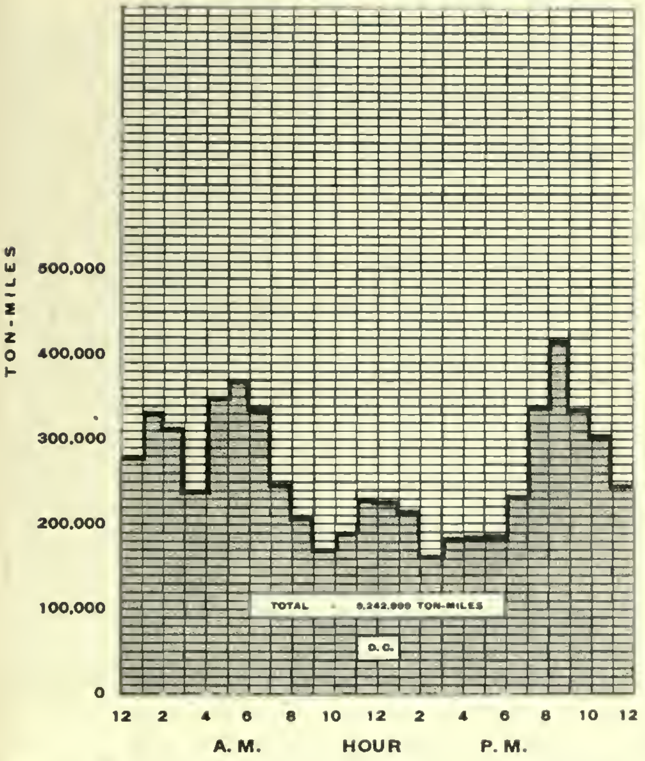

FIG. 576. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Road Freight Service, 2,400-Volt D. C. Operation.

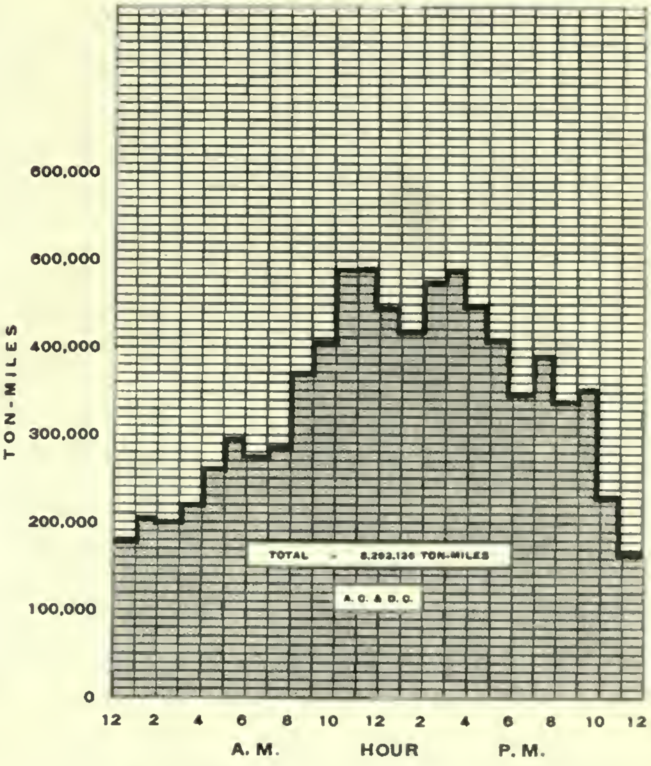

FIG. 578. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Freight Transfer Service, both A. C. and D. C. Operation.

FIG. 579. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Passenger Transfer Service, both A. C. and D. C. Operation

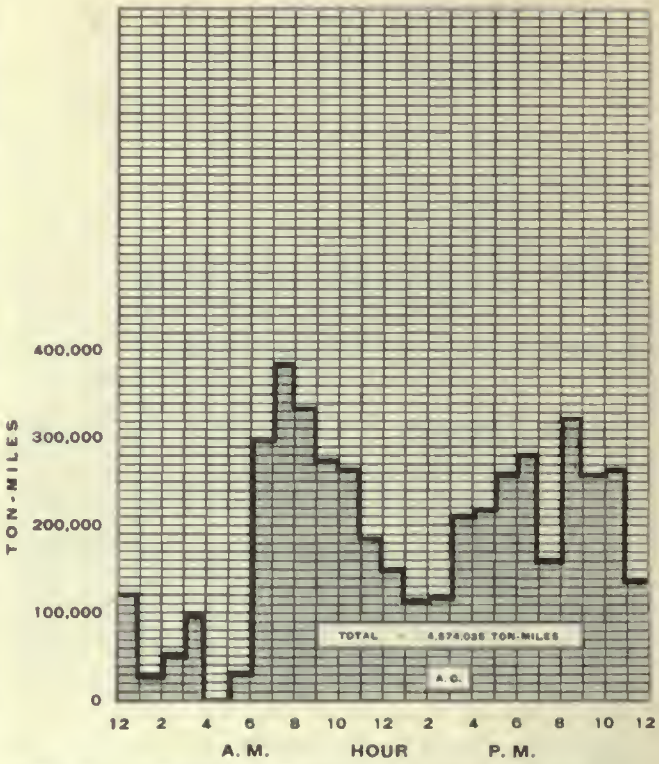

FIG. 581. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Through Passenger Service, 11,000-Volt A. C. Operation.

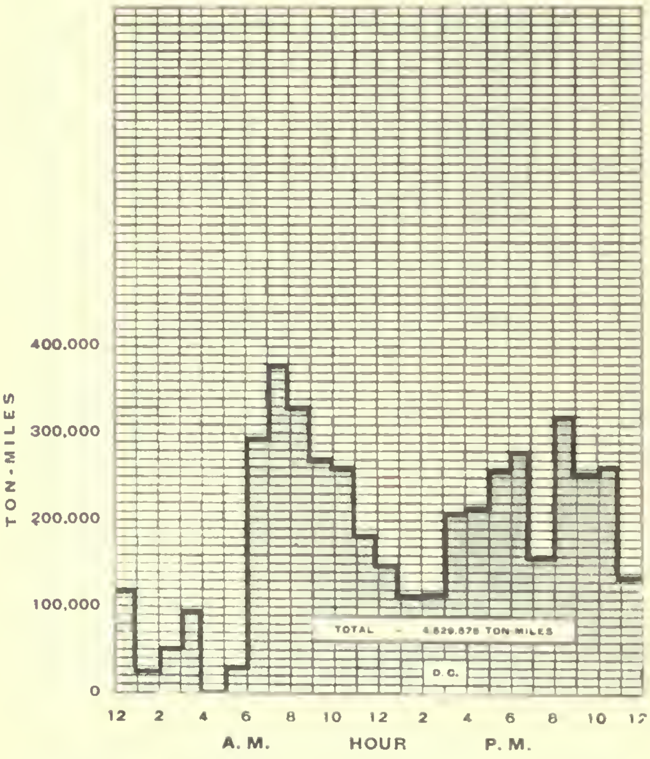

FIG. 580. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Through Passenger Service, 2,400-Volt D. C. Operation.

FIG. 582. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Suburban Passenger Service with Locomotives, 2,400-Volt D. C. Operation.

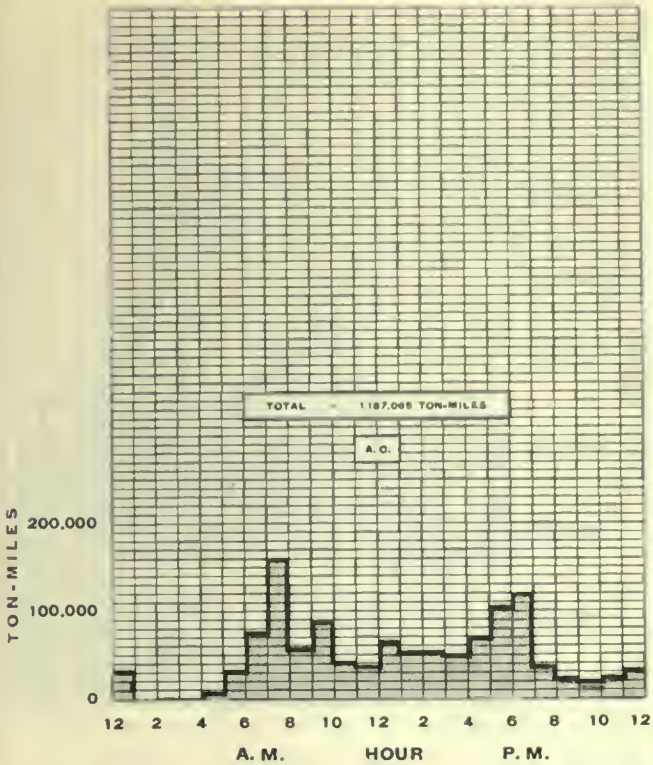

FIG. 583. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Suburban Passenger Service with Locomotives, 11,000-Volt A. C. Operation.

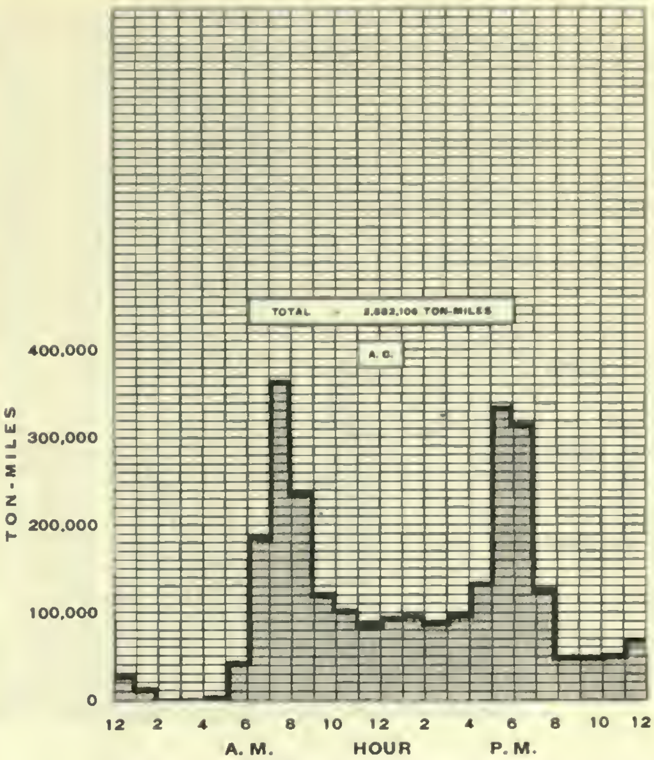

FIG. 585. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Suburban Passenger Service with Multiple-Unit Cars, 11,000-Volt A. C. Operation.

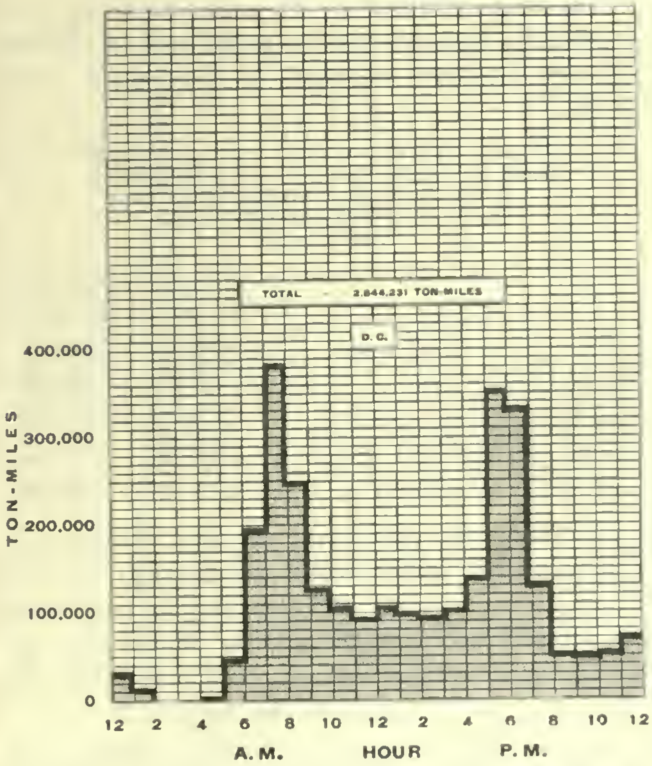

FIG. 584. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Suburban Passenger Service with Multiple-Unit Cars, 2,400-Volt D. C. Operation.

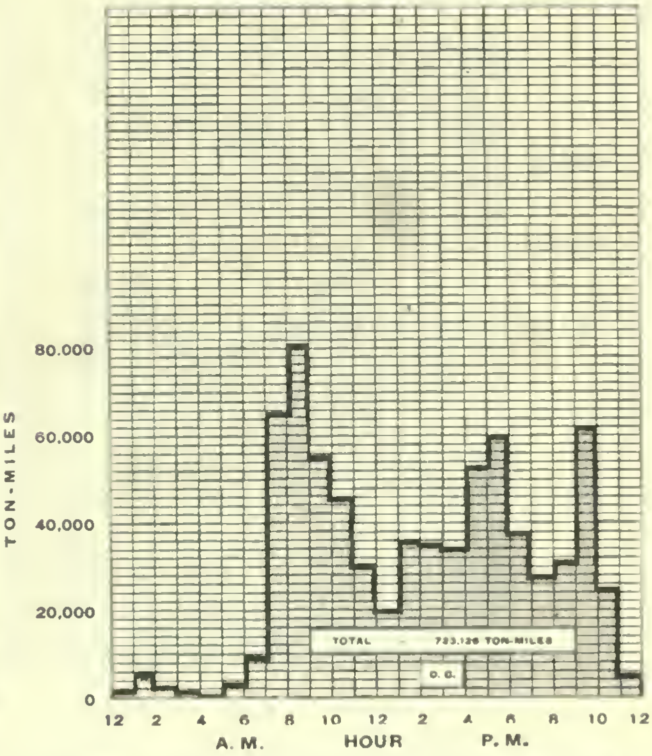

FIG. 586. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Make-Up and Put-Away Passenger Service, 2,400-Volt D. C. Operation.

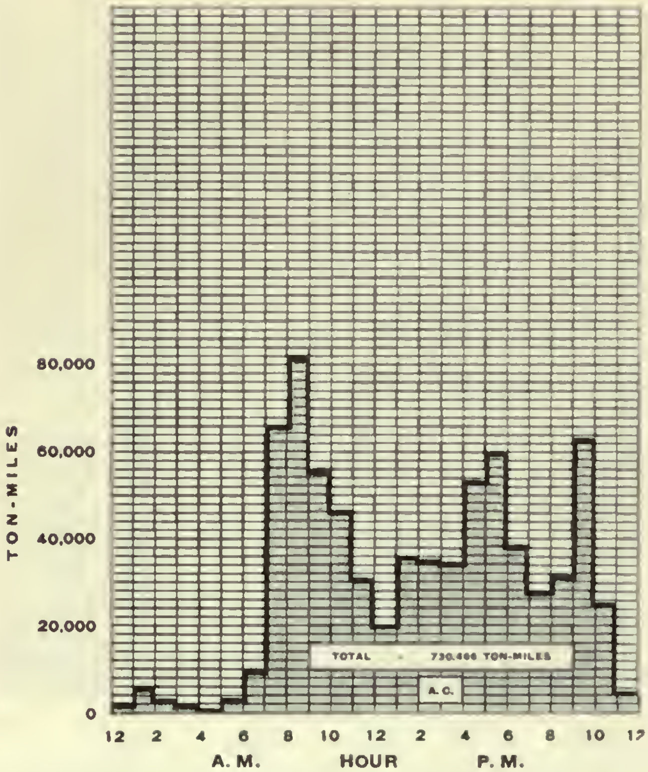

FIG. 587. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for Make-Up and Put-Away Passenger Service, 11,000-Volt A. C. Operation.

FIG. 588. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for All Classes of Service Combined, 2,400-Volt D. C. Operation.

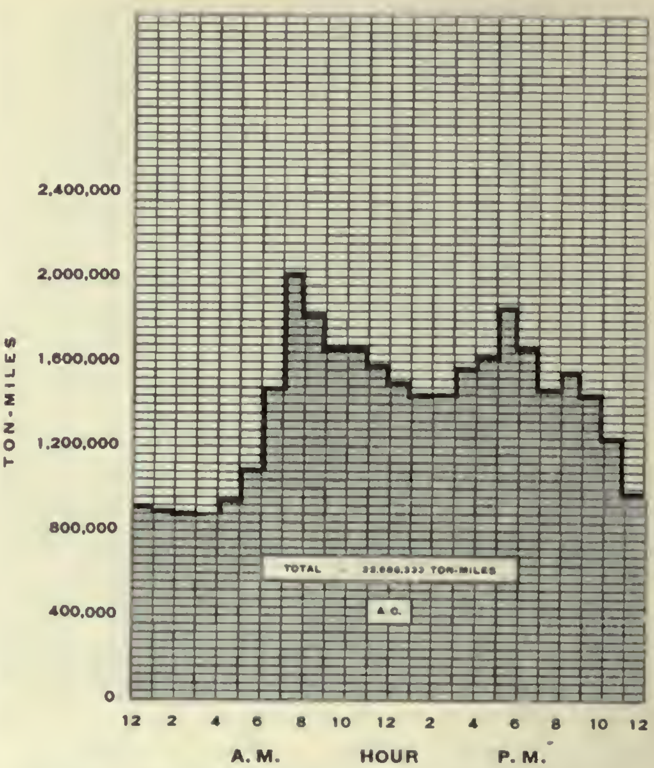

FIG. 589. TRAFFIC CHART. Hourly Ton-Mile Diagram for the Average October Day for All Classes of Service Combined, 11,000-Volt A. C. Operation.

The total number of ton-miles to be handled electrically in each service under each of the two electric traction systems is shown by table CCXLIX.

TABLE CCXLIX. TOTAL NUMBER OF TON-MILES TO BE HANDLED ELECTRICALLY IN EACH SERVICE, BASED UPON THE AVERAGE DAY OF THE OCTOBER REPORT PERIOD
(Basis of 1912)

Service	2,400-Volt D.C. System Ton-Miles	11,000-Volt A.C. System Ton-Miles
Yard	9,554,316	9,554,316
Road freight	6,242,988	6,323,517
Freight transfer	8,252,126	8,252,126
Passenger transfer	375,678	375,678
Through passenger	4,529,575	4,574,025
Suburban passenger with locomotives	1,168,885	1,187,065
Suburban passenger with multiple-unit cars	2,844,231	2,692,109
Make-up and put-away	723,126	730,496
Totals of all combined	33,690,925	33,689,332

A tabulated statement of the locomotive-mileage and multiple-unit car-mileage for the average day of the October report period for both the direct current and the alternating current systems of traction, by roads and by classes of service, is presented as table CCL.

A tabulated statement of the number of ton-miles of traffic to be handled during the average October day under the 2,400-volt direct current

TABLE CCL. ELECTRIC LOCOMOTIVE-MILEAGE AND MULTIPLE-UNIT CAR-MILEAGE FOR THE AVERAGE DAY OF THE OCTOBER REPORT PERIOD

(Basis of 1912)

Railroad	Locomotive-Mileage									Multiple-Unit Car Mileage			
	Yard	Road Freight	Freight Transfer	Passenger Transfer	Through Passenger	Suburban Loco-motive	Make-Up and Put-Away	Total Loco-motive-Mileage	Per Cent of Total	Multiple-Unit	Make-Up and Put-Away	Total	Per Cent of Total
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Atchison, Topeka & Santa Fe Railway	460	159	136	28.6	209.4	0	17.6	1,010.6	1.8	0	0	0	0
Baltimore & Ohio Railroad	298	252	232	0	346.4	36	0	1,164.4	2.1	0	0	0	0
Baltimore & Ohio Chicago Terminal Railroad	756	0	398	0	0	153	0	1,307.0	2.4	0	0	0	0
Calumet, Hammond & Southeastern Railroad	97	0	0	0	0	0	0	97.0	.2	0	0	0	0
Chesapeake & Ohio Railway of Indiana	0	0	42	0	135.9	0	0	177.9	.3	0	0	0	0
Chicago & Alton Railroad	522	80	206	27.1	186.6	0	100.8	1,122.5	2.1	0	0	0	0
Chicago & Calumet River Railroad	106	0	0	0	0	0	0	106.0	.2	0	0	0	0
Chicago & Eastern Illinois Railroad	202	65	182	0	397.5	124	115.0	1,085.5	2.0	0	0	0	0
Chicago & Erie Railroad	0	0	0	0	249.1	0	72.8	321.9	.5	0	0	0	0
Chicago & North Western Railway	4,351	807	1,132	158.2	1,878.8	1,347	646.3	10,320.3	18.9	15,236	1,012	16,248	31.7
Chicago & Western Indiana Railroad and the Belt Railway of Chicago	1,291	0	1,403	232.4	0	0	0	2,926.4	5.3	1,680	0	1,680	3.3
Chicago, Burlington & Quincy Railroad	1,021	241	664	90.1	180.6	131	108.9	2,436.6	4.4	4,484	190	4,674	9.1
Chicago Great Western Railroad	299	28	39	0	73.3	10	0	449.3	.8	0	0	0	0
Chicago, Indiana & Southern Railroad	......	......	0	0	145.5	0	43.2	188.7	.3	0	0	0	0
Chicago, Indianapolis & Louisville Railway	45	71	158	3.5	328.3	0	0	605.8	1.1	0	0	0	0
Chicago Junction Railway	2,180	0	0	0	0	0	0	2,180.0	4.0	0	0	0	0
Chicago, Milwaukee & St. Paul Railway	2,830	437	749	154.8	700.8	463	293.6	5,628.2	10.3	0	0	0	0
Chicago River & Indiana Railroad*	......	......	......	......	......	......	......	......	......	......	......	......	......
Chicago, Rock Island & Pacific Railway	1,011	50	546	39.9	474.1	0	150.0	2,271.0	4.2	5,466	0	5,466	10.6
Chicago Short Line Railway†	......	......	......	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Railway‡	......	......	......	......	......	......	......	......	......	......	......	......	......
Chicago, West Pullman & Southern Railroad	351	0	17	0	0	0	0	368.0	.7	0	0	0	0
Elgin, Joliet & Eastern Railway	1,577	0	56	0	0	0	0	1,633.0	3.0	0	0	0	0
Grand Trunk Western Railway	189	210	70	17.1	154.1	185	147.9	973.1	1.8	0	0	0	0
Illinois Central Railroad	1,109	356	342	3.2	562.1	161	83.1	2,616.4	4.8	17,341	0	17,341	33.8
Illinois Northern Railway	148	0	30	0	0	0	0	178.0	.3	0	0	0	0
Indiana Harbor Belt Railroad	84	0	131	0	0	0	0	215.0	.4	0	0	0	0
Lake Shore & Michigan Southern Railway	1,053	597	397	197.9	943.4	179	244.8	3,612.1	6.6	4,113	0	4,113	8.0
Manufacturers' Junction Railway	0	0	13	0	0	0	0	13.0	.1	0	0	0	0
Michigan Central Railroad	661	59	392	14.3	443.2	211	0	1,780.5	3.3	0	0	0	0
Minneapolis, St. Paul & Sault Ste. Marie Railway	65	0	85	0	80.5	32	20.4	282.9	.5	0	0	0	0
New York, Chicago & St. Louis Railroad	368	232	220	65.0	155.2	0	0	1,040.2	1.9	0	0	0	0
Pere Marquette Railroad	257	41	106	0	195.7	20	0	619.7	1.1	0	0	0	0
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	1,187	655	525	0	53.6	108	7.0	2,535.6	4.6	0	0	0	0
Pittsburgh, Fort Wayne & Chicago Railway	1,482	689	371	50.9	680.1	234	41.8	3,548.8	6.4	1,710	76	1,786	3.5
Pullman Railroad	125	0	0	0	0	0	0	125.0	.2	0	0	0	0
Wabash Railroad	627	340	196	0	315.8	242	140.0	1,860.8	3.4	0	0	0	0
Totals	24,752	5,369	8,838	1,083.0	8,890.0	3,636	2,233.2	54,801.2	100.0	50,030	1,278	51,308§	100.0

* Included with Chicago Junction Railway.

† No report.

‡ Included with the Chicago & Western Indiana Railroad.

§ The total multiple-unit car-mileage of 51,308 is equivalent to 11,328 multiple-unit train miles.

system of traction is presented by roads and by classes of service as table CCLI.

211.02 Method of Determining Energy Required: The amount of energy in kilowatt-hours which will be required at the cars or locomotives or "at the pantograph," has been determined by multiplying the number of ton-miles in each class of service by the unit representing the watt-hours per ton-mile in that service. These units were determined initially by the well-known time-speed curve method. Curves of the characteristics of motors of the types and sizes selected for the several classes of locomotives and multiple-unit cars (sections 213.055 to 213.059) were obtained from manufacturers. These, combined with data regarding the length of run, the speed, the weight of trains and other factors which were developed as a result of the tests described in chapter 202, and with train resistance formulas gathered from the most reliable sources, formed the basis of the calculations from which the time-speed curves were made. The geographic distribution of the energy at the pantograph was determined by applying the energy units to the ton-miles of electric traffic for each class of service over each route element within the proposed limits of electric operation.

211.03 Train Resistance: Sprague's resistance formula was used for determining the train resistance for suburban passenger service to be performed both by multiple-unit cars and by electric locomotives. The Westinghouse Electric & Manufacturing Company's formula was used for determining the train resistance for all through passenger service. Professor Schmidt's table* was used as a basis for train resistance in road freight, freight transfer and yard switching services. To the resistance as given for a 40-ton

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* "Values of Resistance at Various Speeds for Trains of Different Average Weights per Car," University of Illinois Bulletin, May 30, 1910.

TABLE CCLI. TOTAL NUMBER OF TON-MILES TO BE HANDLED UNDER ELECTRIC OPERATION FOR THE AVERAGE DAY OF THE OCTOBER REPORT PERIOD. 2,400-VOLT D. C. SYSTEM

(Basis of 1912)

Railroad 1	Yard 2	Road Freight 3	Freight Transfer 4	Passenger Transfer 5	Through Passenger 6	Suburban Locomotive 7	Multiple-Unit 8	Make-Up and Put-Away 9	Total 10	Per Cent of Total 11
Atchison, Topeka & Santa Fe Ry	177,444	156,927	52,524	7,644	111,669	0	0	3,129	509,337	1.5
Baltimore & Ohio R. R.	115,234	326,847	228,940	0	159,766	8,784	0	0	839,571	2.4
Baltimore & Ohio Chicago Terminal R. R.	291,838	0	460,483	0	0	33,382	0	0	785,703	2.3
Calumet, Hammond & Southeastern R. R.	37,589	0	0	0	0	0	0	0	37,589	.1
Chesapeake & Ohio Ry. of Indiana	0	0	41,347	0	43,664	0	0	0	85,011	.3
Chicago & Alton R. R.	201,713	111,153	122,607	6,048	97,568	0	0	54,183	593,272	1.8
Chicago & Calumet River R. R.	40,809	0	0	0	0	0	0	0	40,809	.1
Chicago & Eastern Illinois R. R.	77,871	69,793	267,208	0	191,624	36,476	0	52,675	695,647	2.1
Chicago & Erie R. R.	0	0	0	0	91,940	0	0	11,284	103,224	.3
Chicago & North Western Ry	1,679,563	891,876	1,040,680	40,932	898,237	417,888	860,341	232,766	6,062,283	18.0
Chicago & Western Indiana R. R. and the Belt Railway of Chicago	498,275	0	2,122,351	114,553	0	0	94,839	0	2,830,018	8.4
Chicago, Burlington & Quincy R. R.	394,318	59,677	423,556	20,272	118,839	52,871	255,322	34,619	1,359,474	4.0
Chicago Great Western R. R.	115,422	31,871	13,593	0	32,380	3,579	0	0	196,845	.6
Chicago, Indiana & Southern R. R.	0	0	0	0	51,701	0	0	8,964	60,665	.2
Chicago, Indianapolis & Louisville Ry	17,391	59,138	139,747	264	154,221	0	0	0	370,761	1.1
Chicago Junction Ry	841,598	0	0	0	0	0	0	0	841,598	2.8
Chicago, Milwaukee & St. Paul Ry	1,092,277	562,800	680,411	57,513	387,041	155,553	0	110,732	3,046 327	9.0
Chicago River & Indiana R. R.*	......	......	......	......	......	......	......	......	......	......
Chicago, Rock Island & Pacific Ry	390,120	38,449	381,265	22,697	203,630	0	311,507	58,304	1,405,972	4.1
Chicago Short Line Ry.†	......	......	......	......	......	......	......	......	......	......
Chicago Union Transfer Ry.‡	......	......	......	......	......	......	......	......	......	......
Chicago, West Pullman & Southern R. R.	135,445	0	7,836	0	0	0	0	0	143,281	.4
Elgin, Joliet & Eastern Ry	608,761	0	129,045	0	0	0	0	0	737,806	2.2
Grand Trunk Western Ry	72,847	209,470	38,767	2,613	81,949	74,598	0	22,924	503,168	1.4
Illinois Central R. R.	427,972	643,488	377,526	340	265,322	50,717	989,541	12,881	2,767,787	8.2
Illinois Northern Ry	56,997	0	19,153	0	0	0	0	0	76,150	.2
Indiana Harbor Belt R. R.	32,351	0	146,540	0	0	0	0	0	178,891	.5
Lake Shore & Michigan Southern Ry	406,509	936,555	213,975	60,127	585,450	59,035	233,121	67,158	2,561,930	7.6
Manufacturers' Junction Ry	0	0	2,925	0	0	0	0	0	2,925	.1
Michigan Central R. R.	255,378	68,757	301,160	2,065	271,939	79,461	0	0	978,760	2.9
Minneapolis, St. Paul & Sault Ste. Marie Ry	25,059	0	66,939	0	33,397	10,054	0	3,162	138,611	.4
New York, Chicago & St. Louis R. R.	141,998	193,396	154,553	26,011	61,065	0	0	0	577,023	1.7
Pere Marquette R. R.	99,259	33,000	89,726	0	82,887	8,711	0	0	313,583	.9
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	458,256	617,868	301,484	0	36,238	31,427	0	3,039	1,448,312	4.3
Pittsburgh, Fort Wayne & Chicago Ry	571,912	870,126	289,896	14,599	424,040	87,925	99,560	25,606	2,383,664	7.1
Pullman Railroad	48,101	0	0	0	0	0	0	0	48,101	.1
Wabash Railroad	242,009	361,797	137,889	0	145,008	58,424	0	21,700	966,827	2.9
Totals	9,554,316	6,242,988	8,252,126	375,678	4,529,575	1,168,885	2,844,231	723,126	33,690,925	100.0

*Included with Chicago Junction Railway. † No report. ‡ Included with the Chicago & Western Indiana Railroad.

freight car, 50 per cent was added in the case of these services to allow for adverse weather and starting conditions, inferior yard track and other indeterminate factors, and the result thus obtained was accepted as the average resistance for all freight car movements.

Equations expressing these facts are as follows:

Multiple-unit and suburban locomotive service:

$$R=4T+\frac{VT}{6}+\frac{V^2}{3} \quad \text{(Sprague)}$$

Through passenger service:

$$R=4.0+\frac{V}{10}+\frac{10V^2}{36T} \quad \text{(Westinghouse)}$$

Freight service:

$$R=1.5\ (4.15+.041V+.00134V^2)$$

(Schmidt plus 50%)

"R" represents the resistance in pounds per ton, "V" the speed in miles per hour and "T" the weight in tons (2,000 lb.).

These formulas are presented in diagrammatic form by fig. 590.

211.04 Energy Units: To the theoretical units which were obtained from the time-speed diagrams, certain percentages were added to cover lighting and heating in the case of multiple-unit service, severe weather conditions, traffic delays, air compressor motor requirements and indeterminate operating losses which experience has shown to exist. After taking account of these factors, energy units were adopted as shown in table CCLII.

TABLE CCLII. ENERGY UNITS ADOPTED FOR ELECTRIC OPERATION

Service	Watt-Hours per Ton-Mile at the Pantograph	
	2,400-Volt D. C. System	11,000-Volt A. C. System
Yard	59	60
Road freight	25	28
Freight transfer	35	38
Passenger transfer	30	30
Through passenger	36	37
Suburban passenger with locomotives	63	63
Suburban passenger with multiple-unit cars	74	71
Make-up and put-away	30	30

211.05 Energy Required at the Pantograph: The energy required at the pantograph for each hour of the average day is shown for each class of service for the 2,400-volt direct current system by diagrams presented as figs. 591 to 598, inclusive, and for the 11,000-volt alternating current system by diagrams presented as figs. 599 to 606, inclusive.

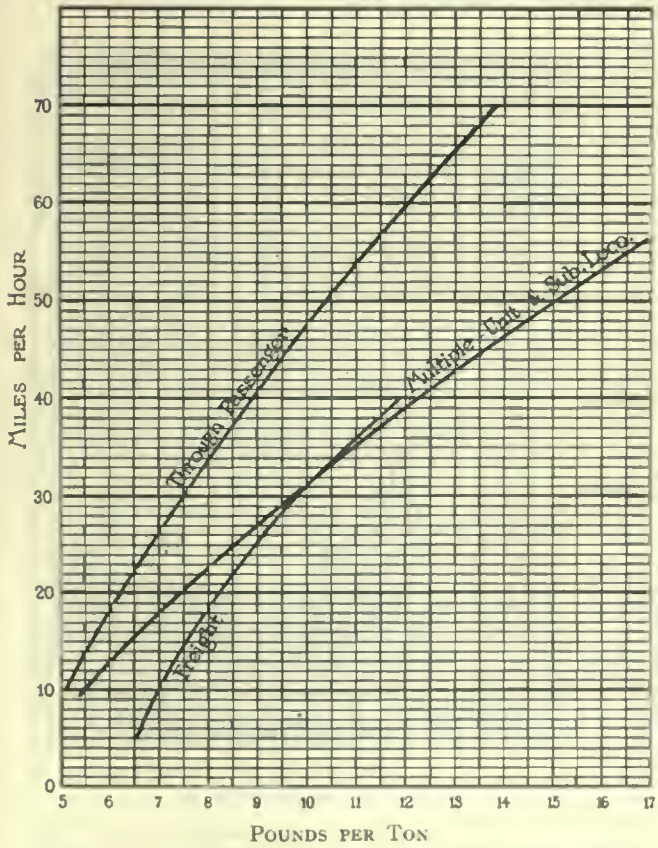


FIG. 590. TRAIN RESISTANCE DIAGRAM

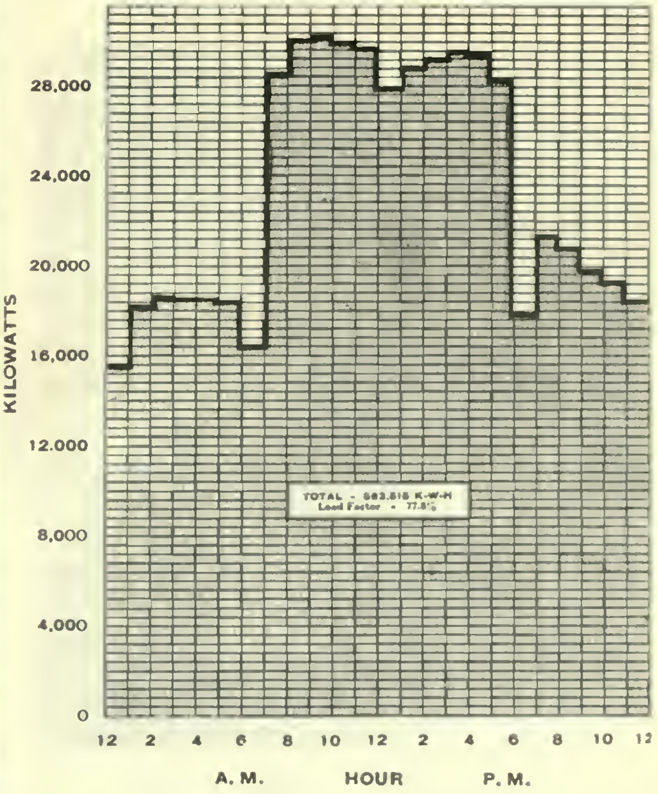


FIG. 591. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C Operation, Yard Service.

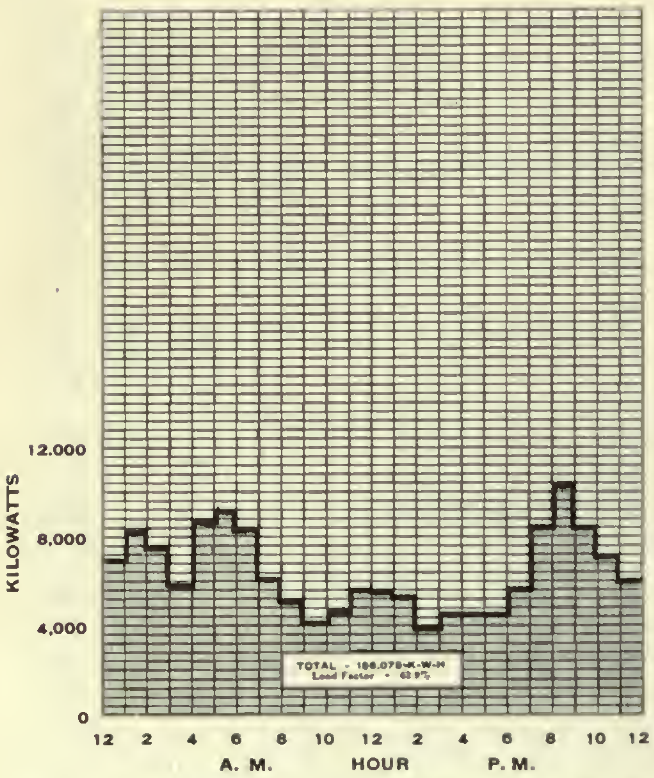


FIG. 592. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Road Freight Service.

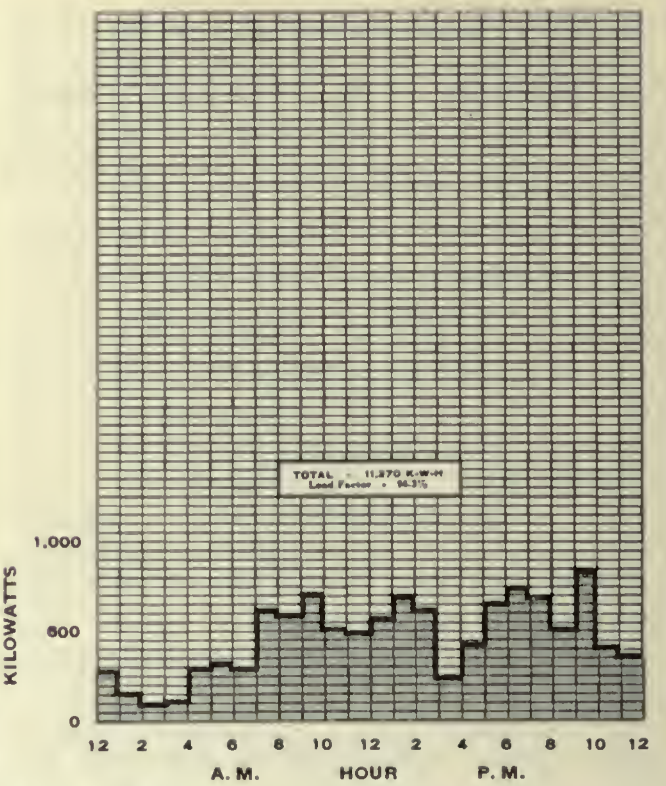


FIG. 594. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Passenger Transfer Service.

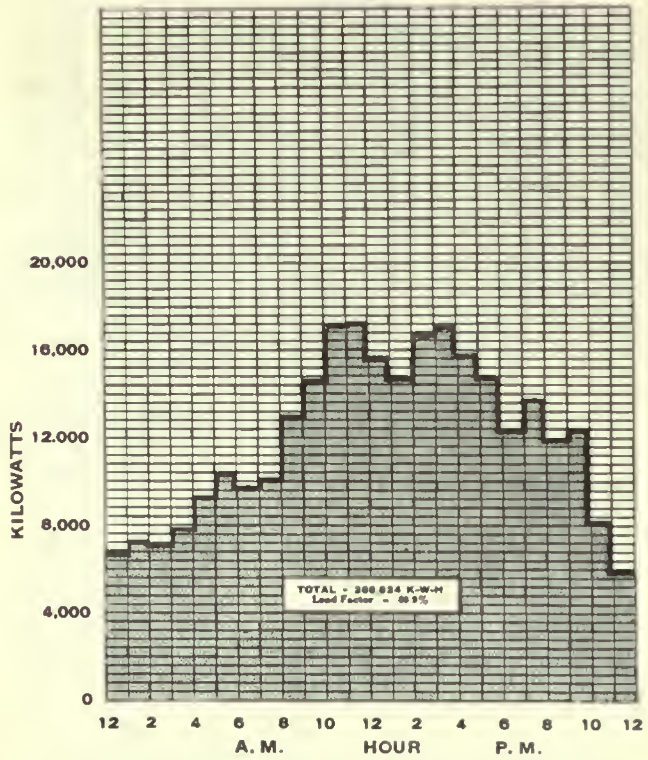


FIG. 593. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Freight Transfer Service.

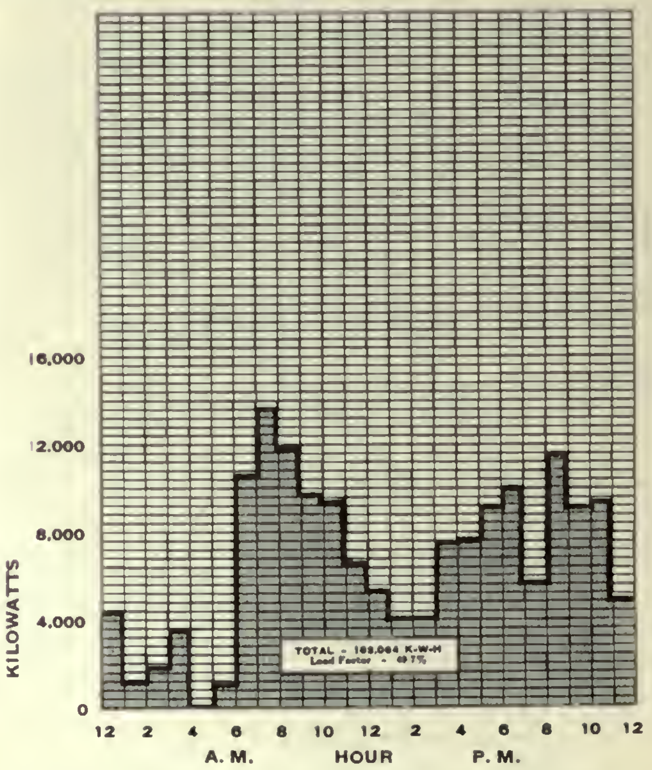


FIG. 595. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Through Passenger Service.

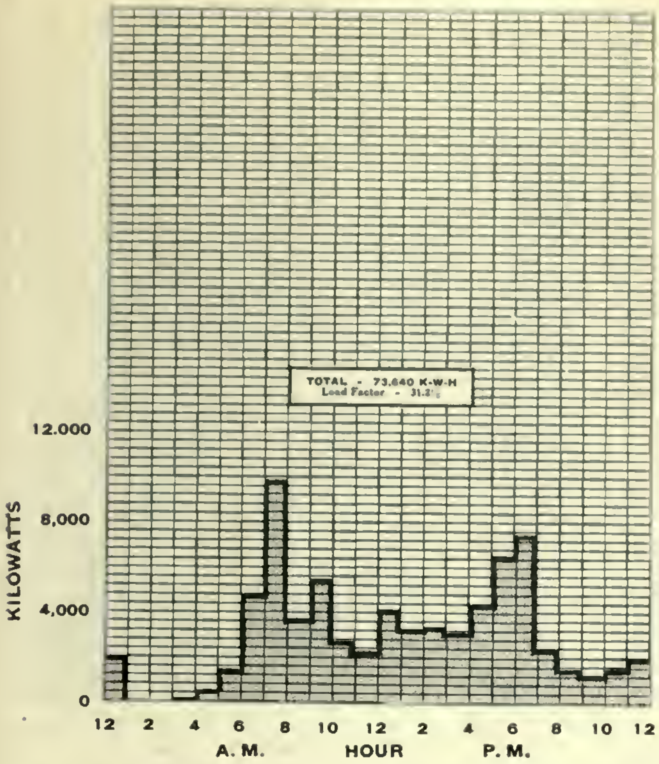


FIG. 596. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Suburban Passenger Service with Locomotives.

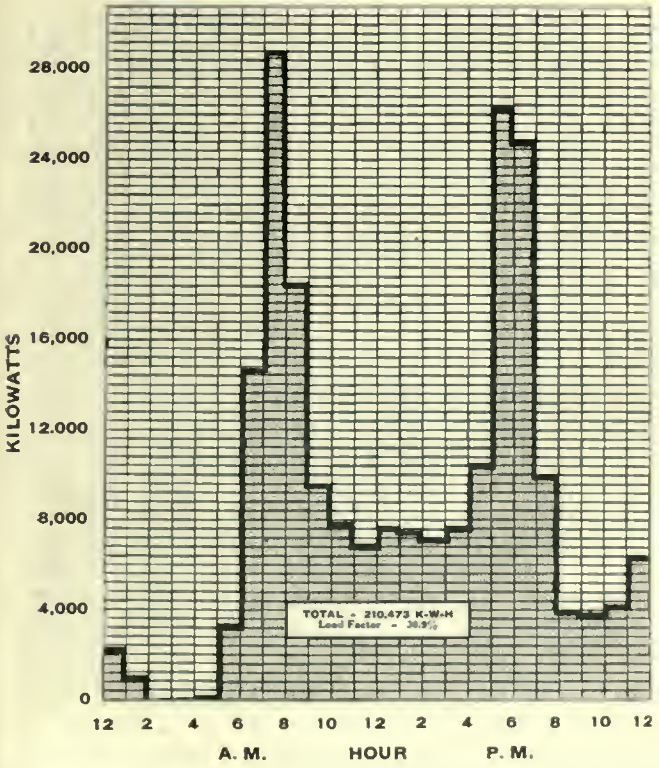


FIG. 597. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Suburban Passenger Service with Multiple-Unit Cars.

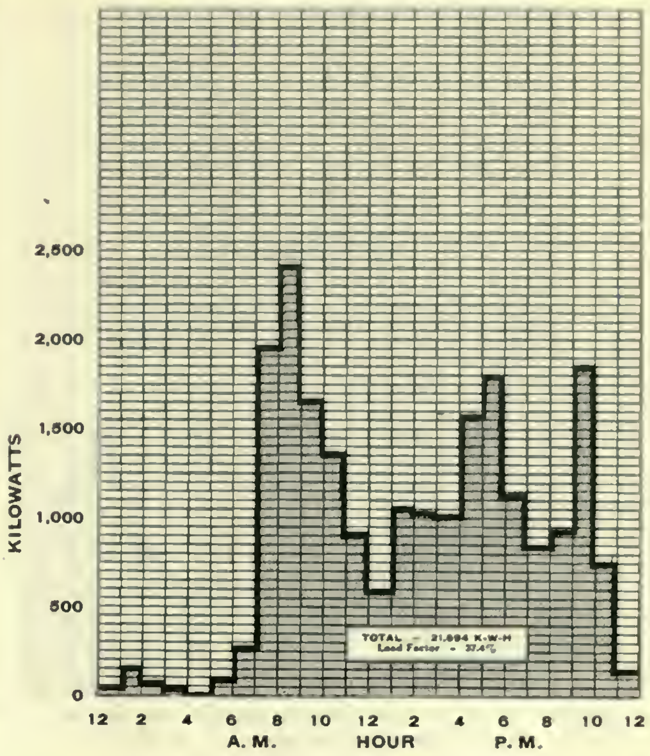


FIG. 598. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Make-Up and Put-Away Passenger Service.

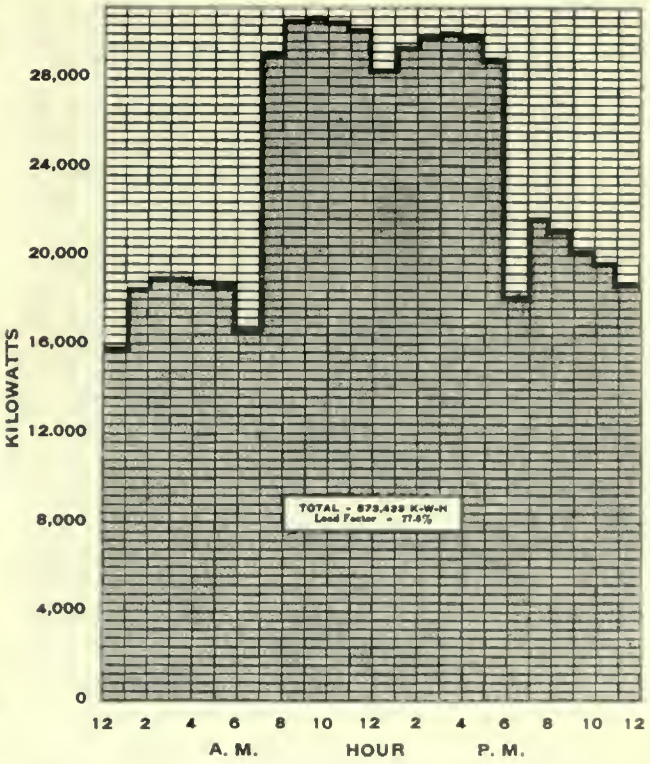


FIG. 599. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 11,000-Volt A. C. Operation, Yard Service.

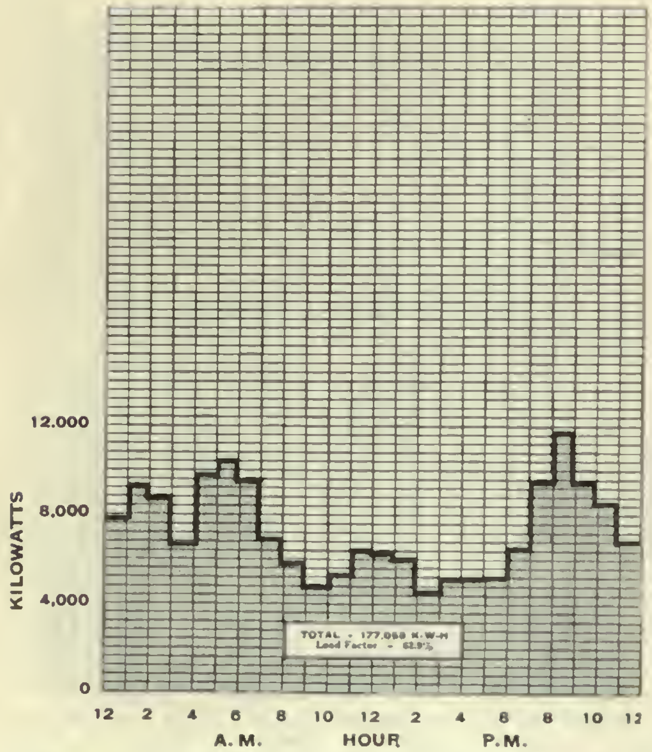


FIG. 600. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 11,000-Volt A. C. Operation, Road Freight Service.

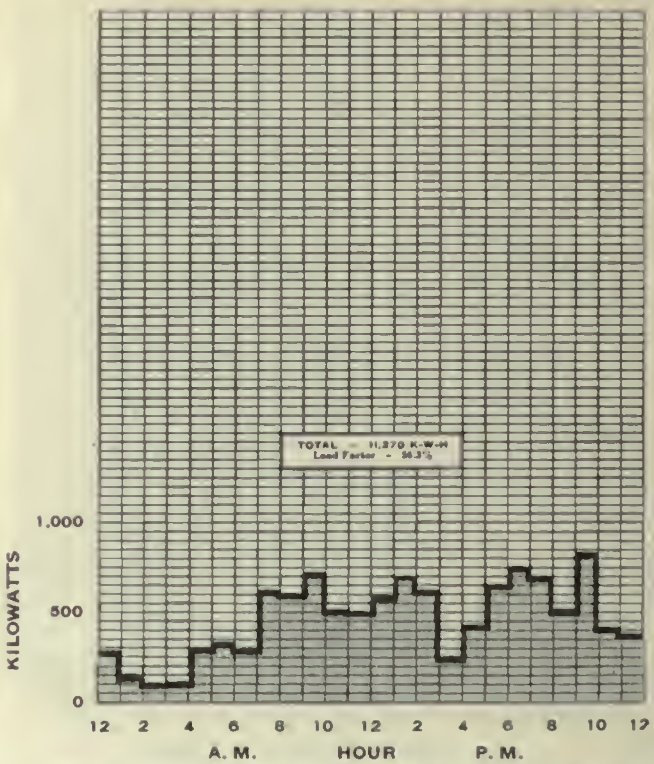


FIG. 602. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 11,000-Volt A. C. Operation, Passenger Transfer Service.

FIG. 601. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 11,000-Volt A. C. Operation, Freight Transfer Service.

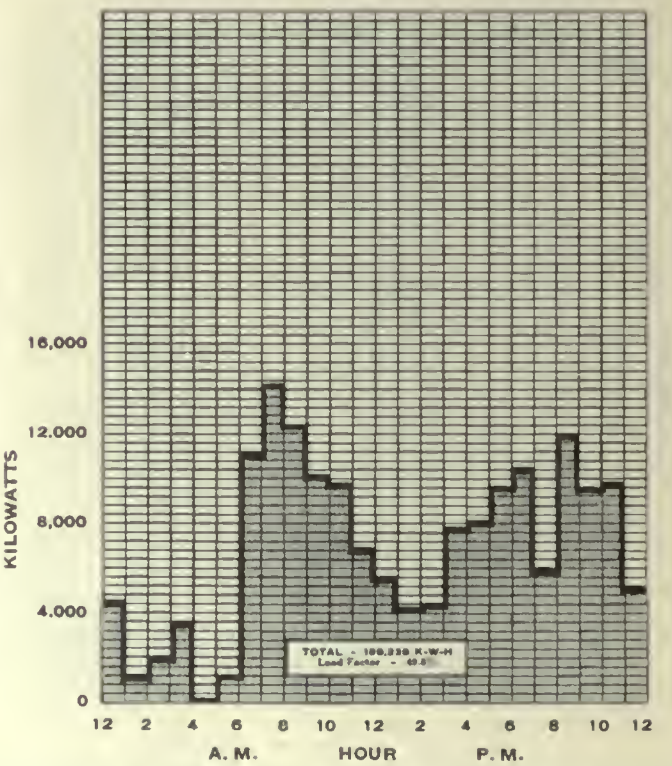


FIG. 603. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 11,000-Volt A. C. Operation, Through Passenger Service.

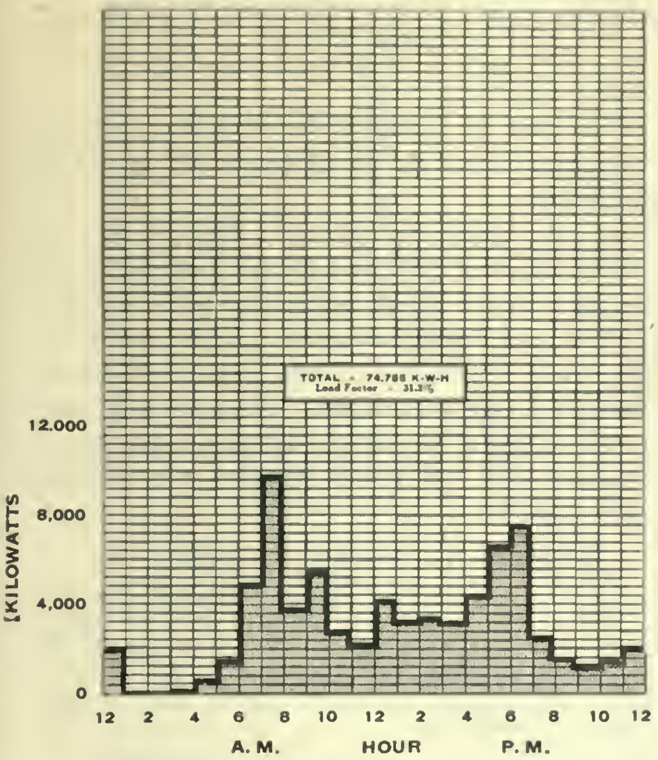


FIG. 604. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 11,000-Volt A. C. Operation, Suburban Passenger Service with Locomotives.

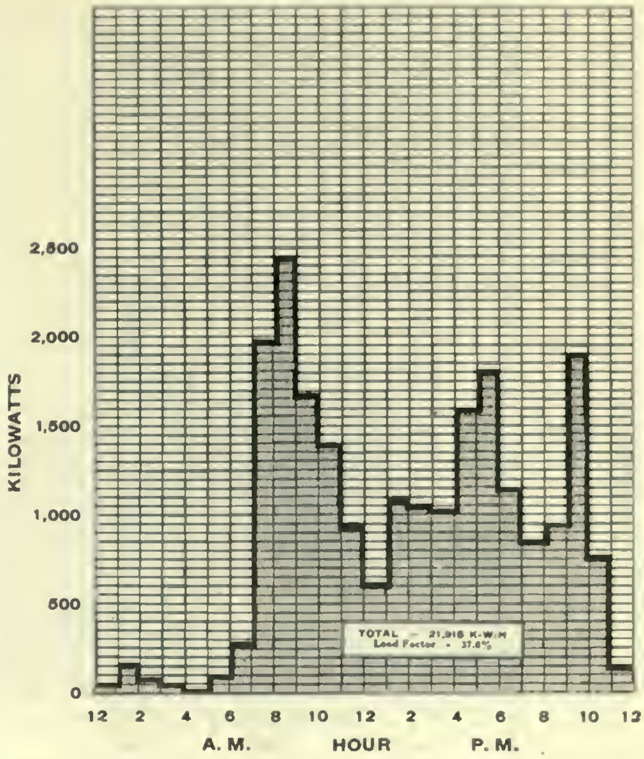


FIG. 606. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 11,000-Volt A. C. Operation, Make-Up and Put-Away Passenger Service.

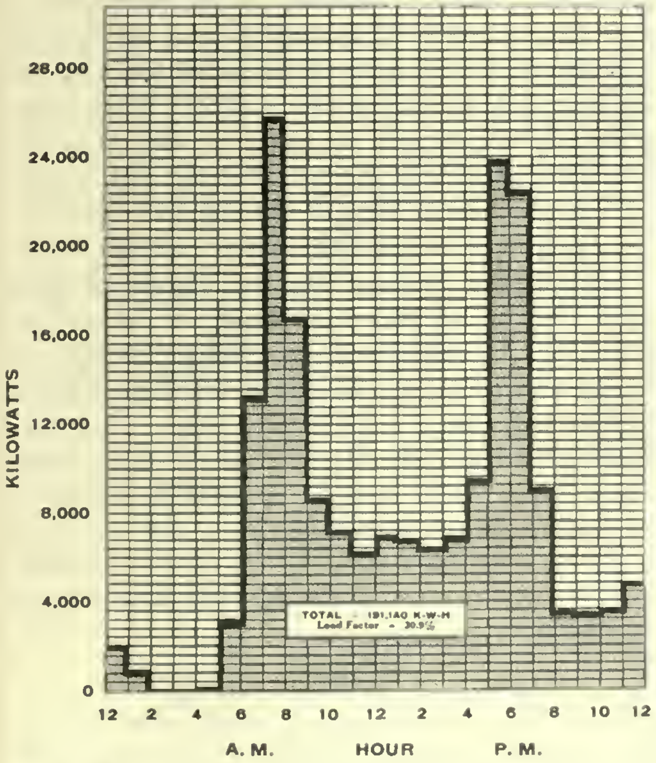


FIG. 605. ENERGY CHART Kilowatt-Hours at the Pantograph for the Average October Day for 11,000-Volt A. C. Operation, Suburban Passenger Service with Multiple-Unit Cars.

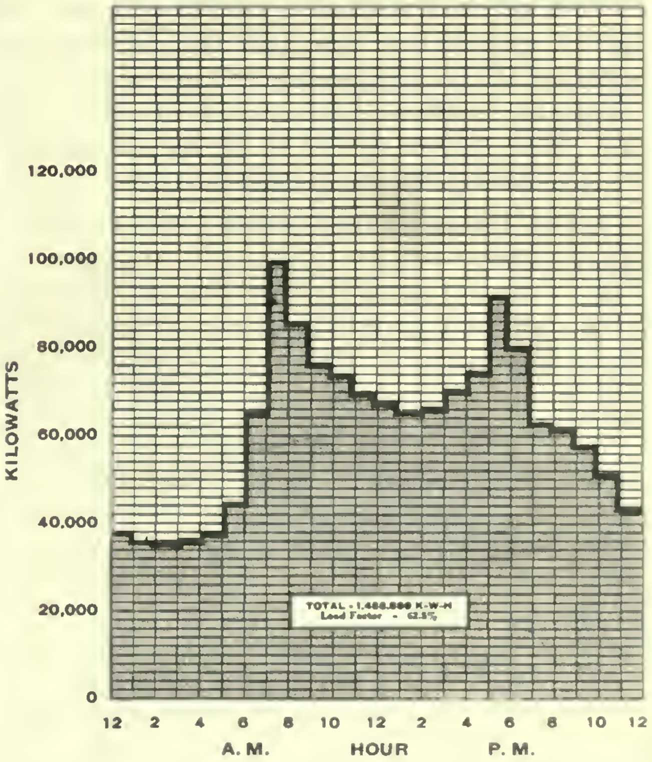


FIG. 607. ENERGY CHART. Total Kilowatt-Hours at the Pantograph for the Average October Day for 2 400-Volt D. C. Operation, All Classes of Service.

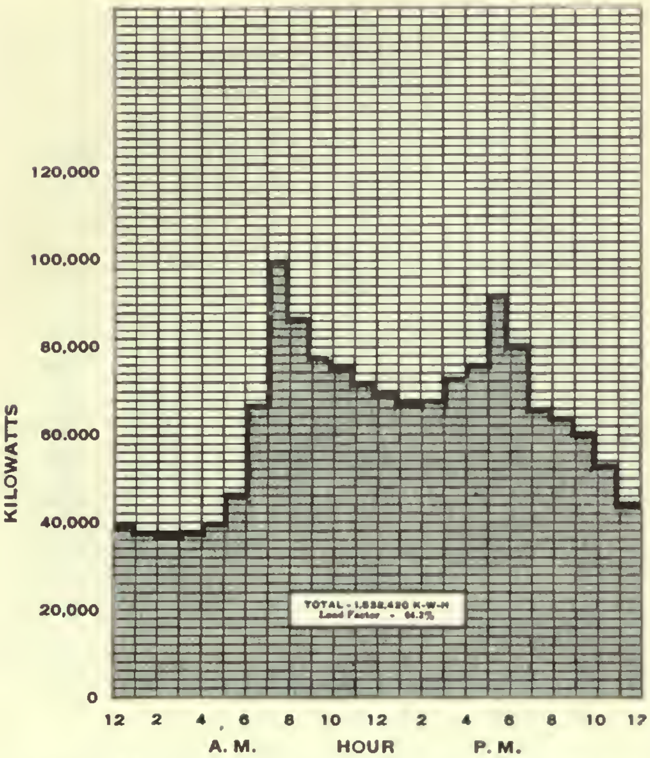


FIG. 608. ENERGY CHART. Total Kilowatt-Hours at the Pantograph for the Average October Day for 11,000-Volt A. C. Operation, All Classes of Service.

The sum of the values given by the diagrams for the several classes of service for each traction system equals the value for the total energy required at the pantograph. These total energy values are shown diagrammatically for the 2,400-volt direct current system by fig. 607, and for the 11,000-volt alternating current system by fig. 608.

211.06 Power Station Location: Based upon the determined geographic distribution of energy, the load center was ascertained and the location of the power station was fixed at a point as near to this theoretical center as the requirements for available water supply would permit (section 213.003).

211.07 Substation Locations: Studies of the geographic distribution of the energy led to the adoption of substation locations for the 2,400-volt direct current system as shown in fig. 609, and for the 11,000-volt alternating current system as shown in fig. 610.

In arriving at the substation locations selected, consideration was given to the voltage drop in the distribution system for direct current, to inductive interference for alternating current, and to the location of large yard loads, the purpose being to locate substations at points at which distribution could be made in several directions and which could be reached over two separate transmission routes.

The load on each of the several substations was determined by calculations of the relative resistance.

211.08 Efficiency Values: The average efficiency values of the transmission and distribution systems were calculated, and those of transformers and rotary converters were assumed on the basis of manufacturers' specifications and calculated load conditions. The efficiency values for the different features of the two systems under consideration, as finally adopted, are shown in table CCLIII.

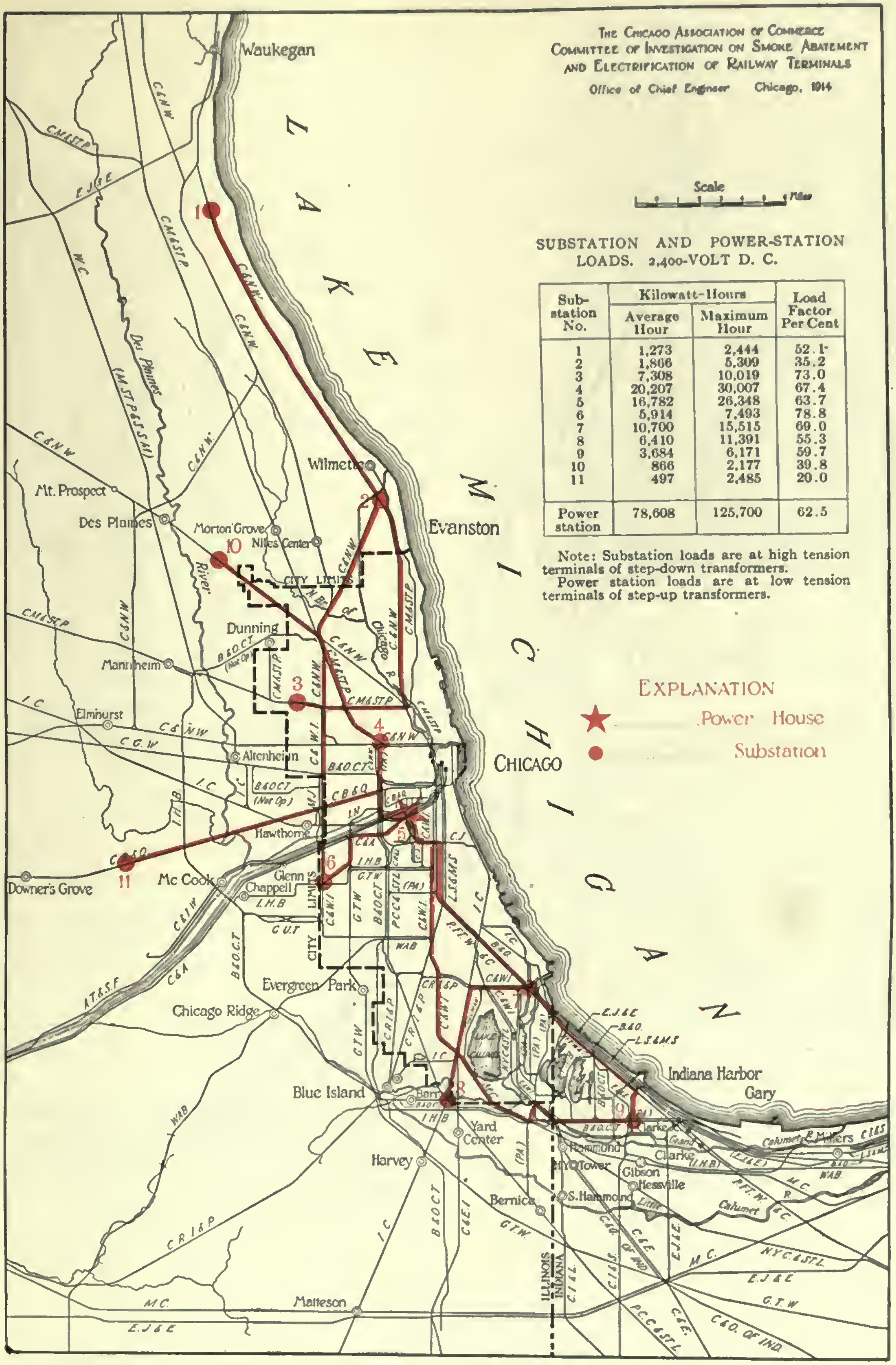
TABLE CCLIII. EFFICIENCY VALUES ADOPTED FOR ELECTRIC OPERATION

Item	2,400-Volt D. C. Per Cent	11,000-Volt A. C. Per Cent
Power station transformers	97.5	97.0
High tension transmission	98.5	98.1
Substation transformers	96.0	95.0
Substation rotary converters	92.0	....
Distribution system	93.0	96.0
Combined efficiency	78.9	86.8

211.09 Diagrams of Power Station Load: By the use of the efficiency values adopted and the diagrams of energy required at the pantograph, diagrams have been prepared showing the hourly load at the low tension terminals of the step-up transformers at the power station. These diagrams are presented as figs. 611 and 612, fig. 611 representing the hourly load for the 2,400-volt direct current system and fig. 612 that for the 11,000-volt alternating current system.

211.10 The Average Day as Compared with Each Day of the Average Week: It should be noted that the energy curves show the energy for the average October day which fairly represents the average day of the entire year. Seasonal variations in the flow of traffic have already been discussed (chapter 202). Calculations based on the daily records obtained from the railroads show that the daily variation on a ton-mile basis for the various days of the average week is substantially as follows:

Energy required on	Sunday	76.9	Per cent of that required on average day
	Monday	100.9	
	Tuesday	103.6	
	Wednesday	104.5	
	Thursday	105.5	
	Friday	103.5	
	Saturday	105.1	

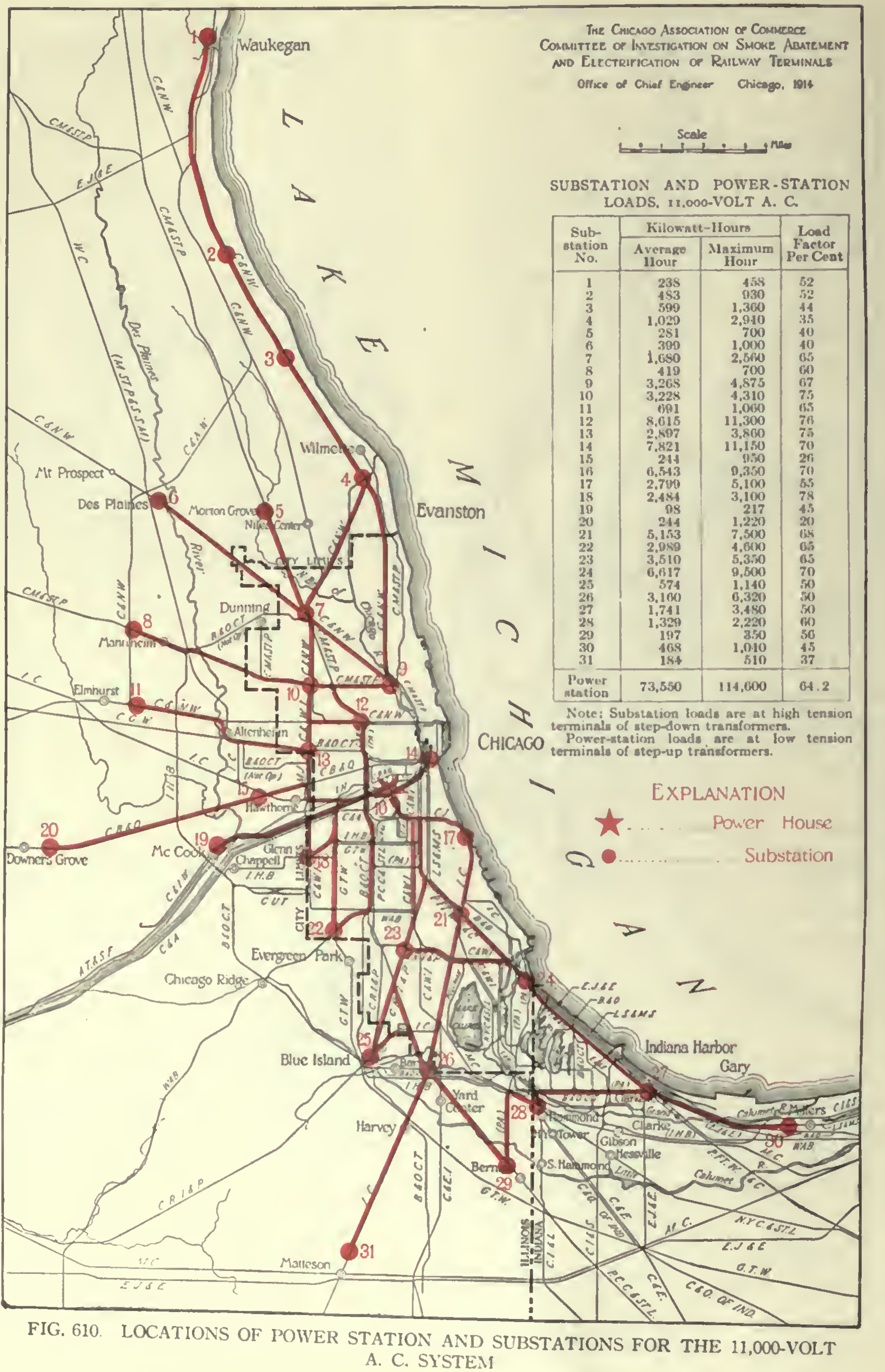


SUBSTATION AND POWER-STATION LOADS. 2,400-VOLT D. C.

Sub-station No.	Kilowatt-Hours		Load Factor Per Cent
	Average Hour	Maximum Hour	
1	1,273	2,444	52.1
2	1,866	5,309	35.2
3	7,308	10,019	73.0
4	20,207	30,007	67.4
5	16,782	26,348	63.7
6	5,914	7,493	78.8
7	10,700	15,515	69.0
8	6,410	11,391	55.3
9	3,684	6,171	59.7
10	866	2,177	39.8
11	497	2,485	20.0
Power station	78,608	125,700	62.5

Note: Substation loads are at high tension terminals of step-down transformers.
Power station loads are at low tension terminals of step-up transformers.

FIG. 609. LOCATIONS OF POWER STATION AND SUBSTATIONS FOR THE 2,400-VOLT D. C. SYSTEM



THE CHICAGO ASSOCIATION OF COMMERCE
COMMITTEE OF INVESTIGATION ON SMOKE ABATEMENT
AND ELECTRIFICATION OF RAILWAY TERMINALS
Office of Chief Engineer Chicago, 1914

SUBSTATION AND POWER-STATION LOADS, 11,000-VOLT A. C.

Substation No.	Kilowatt-Hours		Load Factor Per Cent
	Average Hour	Maximum Hour	
1	238	458	52
2	483	930	52
3	599	1,360	44
4	1,029	2,940	35
5	281	700	40
6	399	1,000	40
7	1,680	2,560	65
8	419	700	60
9	3,268	4,875	67
10	3,228	4,310	75
11	691	1,060	65
12	8,615	11,300	76
13	2,897	3,860	75
14	7,821	11,150	70
15	244	950	26
16	6,543	9,350	70
17	2,799	5,100	55
18	2,484	3,100	78
19	98	217	45
20	244	1,220	20
21	5,153	7,500	68
22	2,989	4,600	65
23	3,510	5,350	65
24	6,617	9,500	70
25	574	1,140	50
26	3,160	6,320	50
27	1,741	3,480	50
28	1,329	2,220	60
29	197	350	56
30	468	1,040	45
31	184	510	37
Power station	73,550	114,600	64.2

Note: Substation loads are at high tension terminals of step-down transformers.

Power-station loads are at low tension terminals of step-up transformers.

EXPLANATION

★ .... Power House

● .... Substation

FIG. 610. LOCATIONS OF POWER STATION AND SUBSTATIONS FOR THE 11,000-VOLT A. C. SYSTEM

In general, it may be said that the maximum hour loads for the various week days are practically the same and that the difference in total daily loads is due to a variation in the load factor.

211.11 Energy Requirements by Individual Roads: The foregoing diagrams present characteristics of the load that would result from the combined electric operation of all traffic within the proposed limits prescribed by the plan of electrification. In order to determine the basis upon which to pro-rate to the individual roads the cost of those facilities used jointly for the generation and distribution of the energy, namely, power station, transmission lines and substations, it has been necessary to determine the energy requirements of the individual roads. These requirements are shown by table CCLIV:

Table CCLIV shows for the 2,400-volt direct current system the energy required at the pantograph for each road for the average day, the average hour and the maximum hour. The load factor, or ratio of the average hour load to the maximum hour load, expressed in per cent, and the relation that the daily load and the maximum hour load of each road bear to the respective totals of these items are also shown.

The ratio of the sum of the maximum hour loads of all of the roads, 109,258 kilowatt-hours, to the maximum hour load of the same roads operated jointly, 99,208 kilowatt-hours (fig. 607), is 110 per cent and represents the diversity factor.

211.12 Energy Requirements of a Single Road (Chicago & North Western Railway) by Each of Three Systems of Electrification: To provide a basis upon which to make estimates of the cost of electrifying and operating electrically a single selected road, the Chicago & North Western Railway, by each of three electric traction systems, namely, the overhead contact system with 2,400-volt direct current and with 11,000-volt alternating current, and the third rail system with 600-volt direct current (section 213.117), the energy required to operate all traffic over the tracks of this road alone, by each of the three systems, was determined. The traffic of this road over the tracks of other roads has not been included, it being assumed in this study that only the tracks owned by the Chicago & North Western Railway would be equipped for electric operation

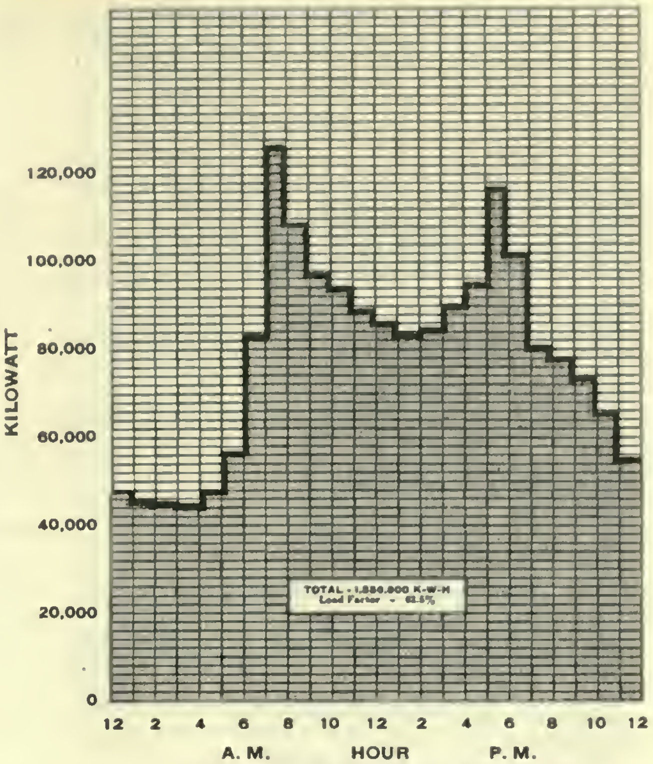


FIG. 611. ENERGY CHART. Total Kilowatt-Hours at the Low Tension Terminals of the Transformers at the Power Station for the Average October Day for 2,400-Volt D. C. Operation, All Classes of Service.

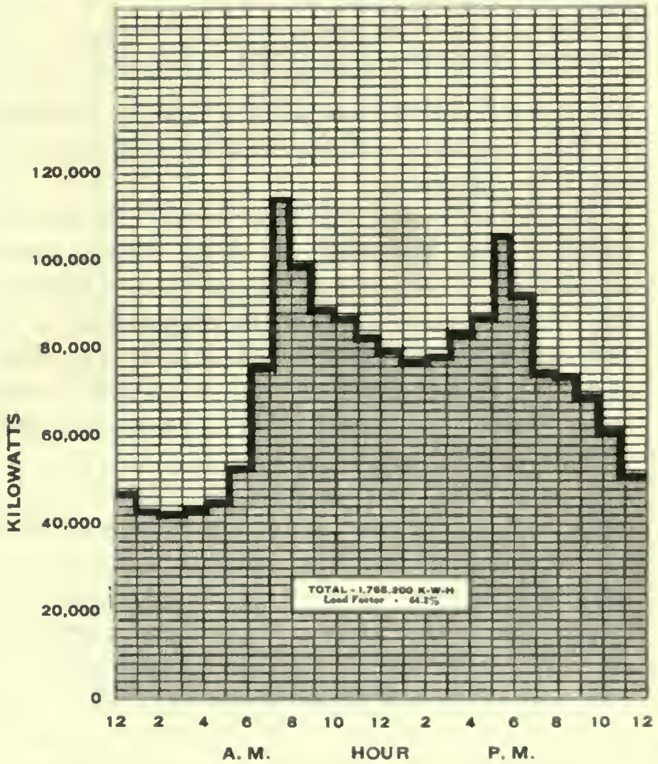


FIG. 612. ENERGY CHART. Total Kilowatt-Hours at the Low Tension Terminals of the Transformers at the Power Station for the Average October Day for 11,000-Volt A. C. Operation, All Classes of Service.

TABLE CCLIV. ENERGY REQUIREMENTS AT PANTOGRAPH—2,400-VOLT DIRECT CURRENT SYSTEM BY ROADS

(Basis of 1912)

Railroad	Average Day		Average Hour	Maximum Hour		Load Factor
	Kilowatt-Hours	Per Cent of Total	Kilowatt-Hours	Kilowatt-Hours	Per Cent of Total	
1	2	3	4	5	6	7
Atchison, Topeka & Santa Fe Railway	20,537	1.38	856	1,325	1.21	64.6
Baltimore & Ohio Railroad	29,333	1.97	1,222	1,604	1.47	76.2
Baltimore & Ohio Chicago Terminal Railroad	35,355	2.38	1,473	2,067	1.89	71.3
Calumet, Hammond & Southeastern Railroad	2,217	0.15	92	148	0.14	62.2
Chesapeake & Ohio Railway of Indiana	3,016	0.20	126	349	0.32	36.1
Chicago & Alton Railroad	24,388	1.64	1,016	1,589	1.45	63.9
Chicago & Calumet River Railroad	2,407	0.16	100	137	0.13	73.0
Chicago & Eastern Illinois Railroad	26,400	1.77	1,100	1,890	1.73	58.2
Chicago & Erie Railroad	3,640	0.24	156	885	0.81	17.6
Chicago & North Western Railway	288,228	19.37	12,010	23,438	21.46	51.7
Chicago & Western Indiana Railroad and the Belt Railway of Chicago*	113,567	7.63	4,732	6,915	6.33	68.4
Chicago, Burlington & Quincy Railroad	67,655	4.54	2,819	6,464	5.92	43.6
Chicago Great Western Railroad	9,704	0.65	404	885	0.81	45.6
Chicago, Indiana & Southern Railroad	3,126	0.21	130	663	0.61	19.6
Chicago, Indianapolis & Louisville Railway	11,812	0.79	492	1,054	0.96	46.7
Chicago Junction Railway†	49,638	3.33	2,064	2,746	2.51	75.2
Chicago, Milwaukee & St. Paul Railway	130,512	8.78	5,438	8,117	7.43	67.0
Chicago, Rock Island & Pacific Railway	70,046	4.71	2,919	6,035	5.52	50.2
Chicago Short Line Railway	1,950	0.13	81	126	0.12	64.2
Chicago, West Pullman & Southern Railroad	8,260	0.55	345	426	0.39	81.0
Elgin, Joliet & Eastern Railway	40,317	2.71	1,680	2,526	2.31	66.5
Grand Trunk Western Railway	19,348	1.30	806	1,410	1.29	57.2
Illinois Central Railroad	140,521	9.45	5,855	12,021	11.01	48.7
Illinois Northern Railway	4,043	0.27	168	288	0.26	58.3
Indiana Harbor Belt Railroad	6,999	0.47	292	894	0.82	32.7
Lake Shore & Michigan Southern Railway	100,747	6.77	4,198	7,225	6.61	58.1
Michigan Central Railroad	42,092	2.83	1,754	2,386	2.18	73.5
Minneapolis, St. Paul & Sault Ste. Marie Railway	5,729	0.38	239	605	0.55	39.5
New York, Chicago & St. Louis Railroad	21,617	1.45	901	1,344	1.23	67.0
Pere Marquette Railroad	13,311	0.89	555	1,086	0.99	51.1
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	56,444	3.79	2,352	3,354	3.07	70.1
Pittsburgh, Fort Wayne & Chicago Railway	95,051	6.39	3,960	6,467	5.92	61.2
Pullman Railroad	2,838	0.19	118	254	0.23	46.5
Wabash Railroad	37,711	2.53	1,571	2,535	2.32	62.0
Totals	1,488,559	100.00	62,023	109,258	100.00	......

* Includes Chicago Union Transfer Railway. † Includes Chicago River & Indiana Railroad.

and that movements now made by the locomotives of this road over connecting lines would not be handled electrically.

The methods employed to determine the energy required were the same as those described for determining the energy of the entire system from diagrams of hourly ton-mileage prepared for each service. Similar diagrams of hourly kilowatt-hours at the pantograph or third rail contact shoes were obtained by the use of the same energy units determined and employed for the entire system. The same units were used for the 600-volt determinations as for the 2,400-volt determinations. The diagrams for the three systems are so nearly alike that only those for 2,400 volts are shown. These diagrams for each of the eight classes of service are presented as figs. 613 to 620, inclusive, and for the total of all services as fig. 621.

The kilowatt-hours at the third rail contact shoes, and at the pantograph for the average October day, by classes of service, are shown for each system in table CCLV.

TABLE CCLV. KILOWATT-HOURS AT THE THIRD RAIL CONTACT SHOES AND AT THE PANTOGRAPH FOR THE AVERAGE OCTOBER DAY—CHICAGO & NORTH WESTERN RAILWAY

(Basis of 1912)

Service	600-V. D. C.	2,400-V. D.C	11,000-V. A.C.
1	2	3	4
Yard	99,084	99,084	100,763
Road freight	21,413	21,413	24,292
Freight transfer	31,713	31,713	34,430
Passenger transfer	1,186	1,186	1,186
Through passenger	32,267	32,267	33,509
Suburban passenger with locomotives	26,492	26,492	26,915
Suburban passenger with multiple-unit cars	58,188	64,101	58,311
Make-up and put-away	6,830	6,983	6,966
Totals	277,173	283,239	286,372

The small differences shown in the energy required for multiple-unit and make-up services for 600 volts and for 2,400 volts are due to differences in the weight of rolling equipment. It will also be noted that the total energy given for the 2,400-volt direct current system is less than that shown for the same road in table CCLIV, which includes the energy for all movements of the road regardless of ownership of track. This difference is less than two per cent.

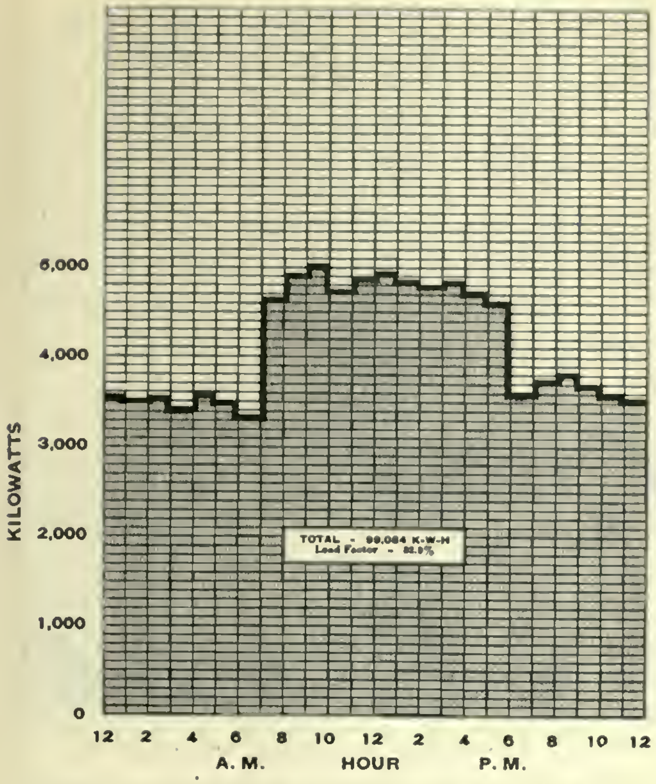


FIG. 613. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Yard Service on the C. & N. W. Ry.

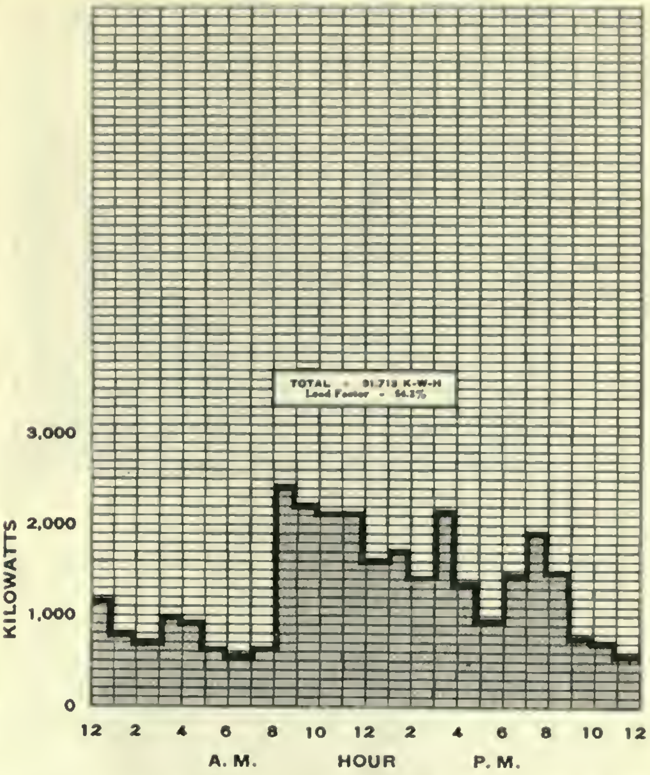


FIG. 615. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Freight Transfer Service on the C. & N. W. Ry.

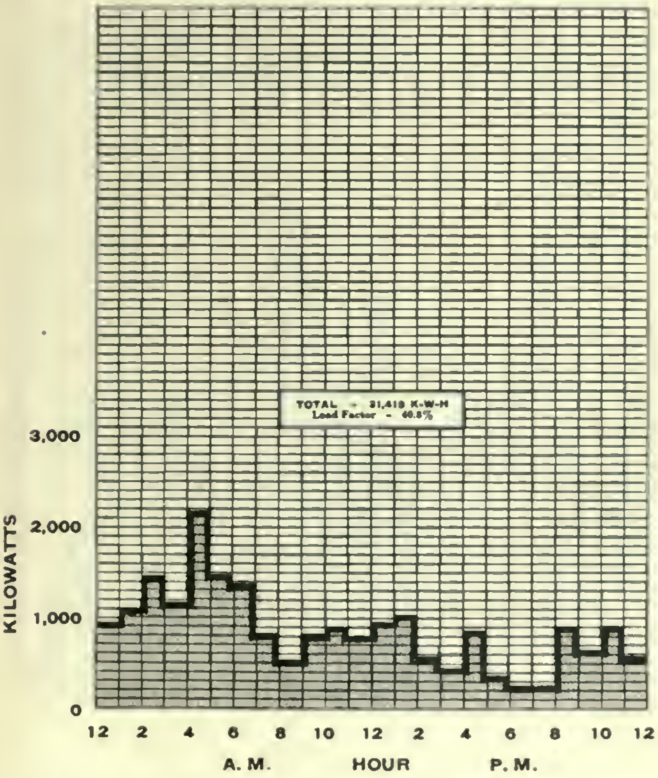


FIG. 614. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Road Freight Service on the C. & N. W. Ry.

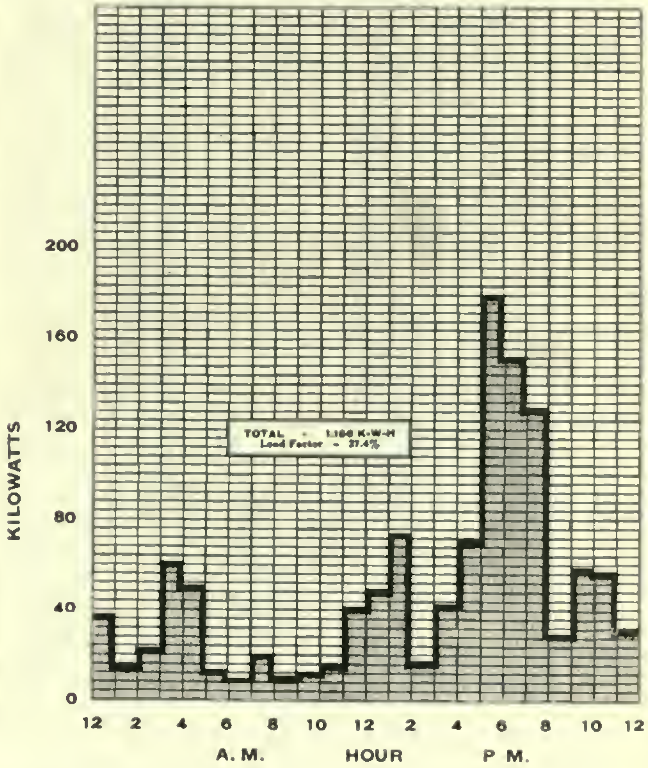


FIG. 616. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Passenger Transfer Service on the C. & N. W. Ry.

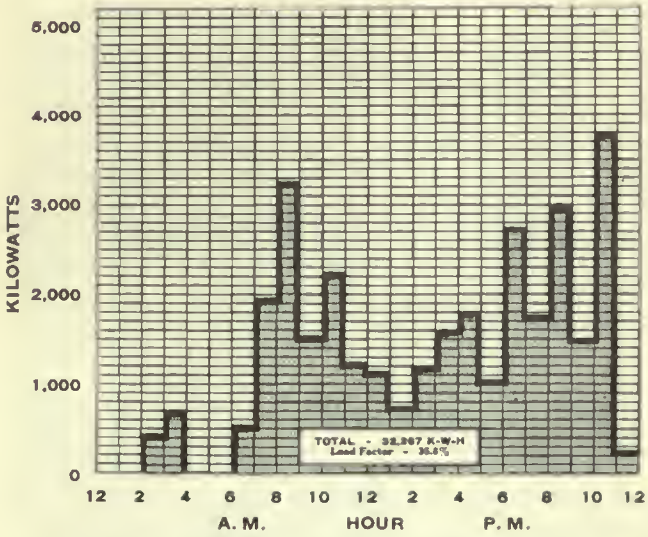


FIG. 617. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Through Passenger Service on the C. & N. W. Ry.

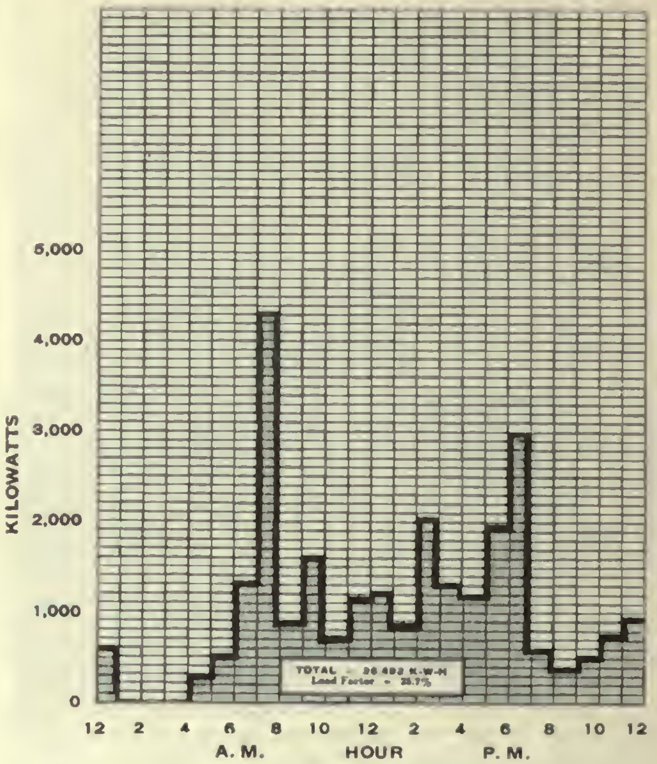


FIG. 618. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Suburban Passenger Service with Locomotives on the C. & N. W. Ry.

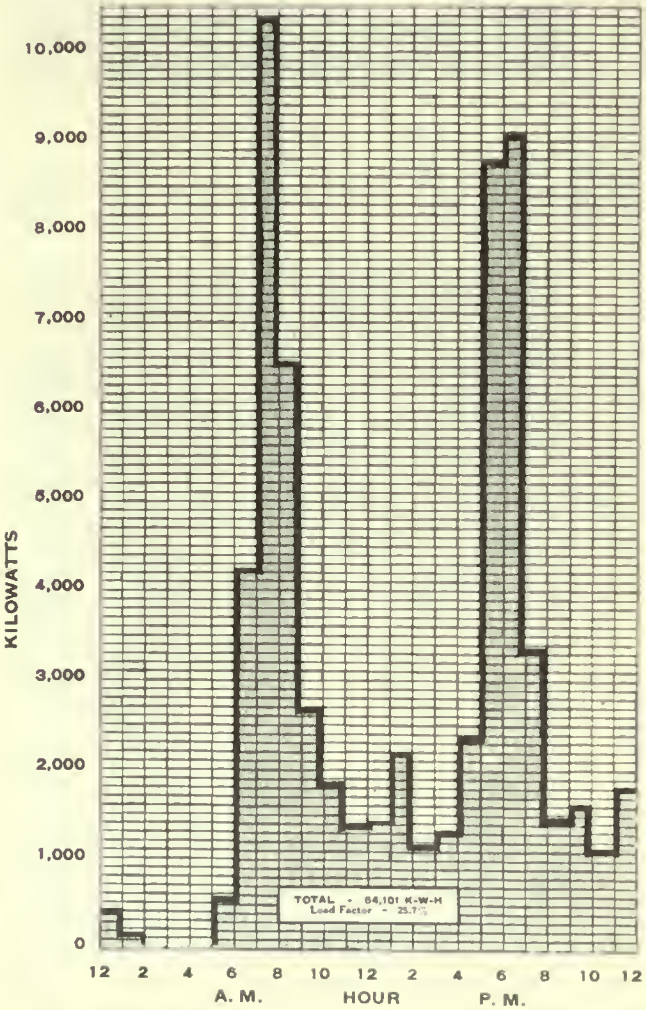


FIG. 619. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Suburban Passenger Service with Multiple-Unit Cars on the C. & N. W. Ry.

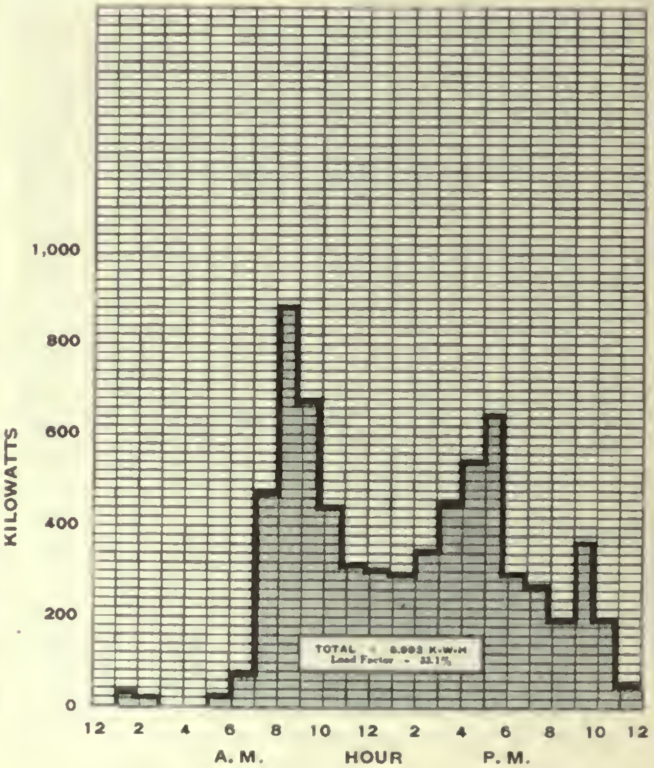


FIG. 620. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, Make-Up and Put-Away Passenger Service on the C. & N. W. Ry.

The location of power station, number and location of substations and transmission line routes, as determined for each of the three systems for the Chicago & North Western Railway, are shown by the maps presented as figs. 623, 624 and 625.

The efficiency values used for determining the power station loads from the load values presented for the trains are given in table CCLVI.

TABLE CCLVI. EFFICIENCY VALUES USED FOR DETERMINING POWER STATION LOADS

Item	600-V. D. C. Per Cent	2,400-V. D. C. Per Cent	11,000-V. A. C. Per Cent
1	2	3	4
Power station transformers	97.5	97.5	97.0
High tension transmission	99.5	99.1	98.7
Substation transformers	95.0	96.0	95.0
Substation rotary converters	91.0	92.0	....
Distribution system	91.0	93.0	96.0
Combined efficiency	76.3	79.4	87.3

It will be noted that, for the 2,400-volt system and for the 11,000-volt system, the same efficiency values have been used as were used for all roads combined (section 211.08) except for the high tension transmission system. Owing to the use of the same transmission potential, 33,000 volts, and the same minimum size of wire, the shorter lines and smaller amount of energy transmitted result in higher efficiencies for the single road than for the entire system.

The load for the average day at the low tension terminals of the step-up transformers at the power station for each of the three systems is shown in table CCLVII.

TABLE CCLVII. LOAD FOR THE AVERAGE DAY AT THE POWER STATION

Item	600-V. D. C.	2,400-V D. C.	11,000-V. A. C.
1	2	3	4
Total output for 24 hrs., kw-hr.	363,267	356,724	328,033
Average hour output, kw.	15,136	14,864	13,668
Load factor, per cent	51.9	50.9	52.7

The diagrams of hourly power station loads are so nearly the same for the three systems that only that for 2,400 volts is presented. This is shown as fig. 622.

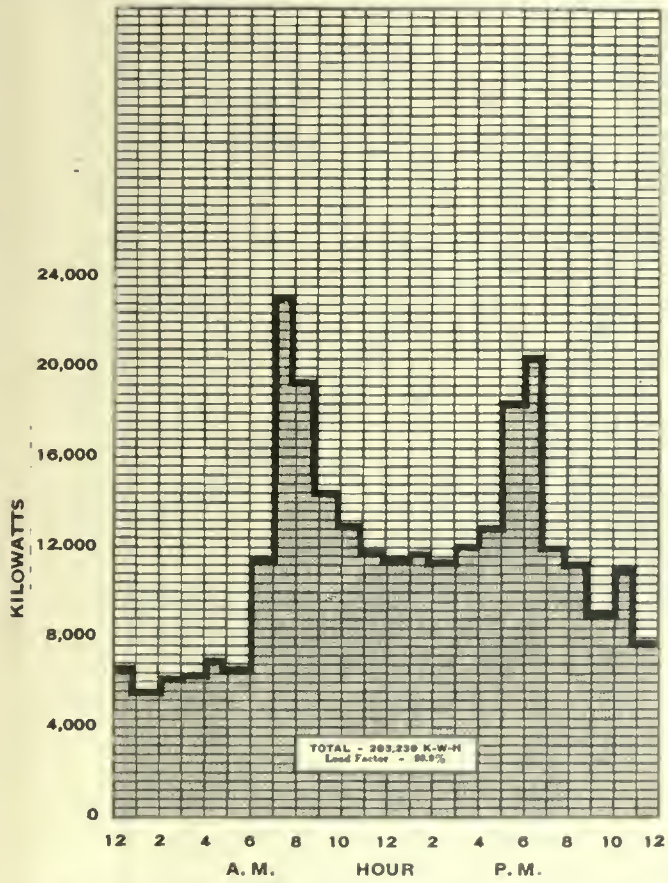


FIG. 621. ENERGY CHART. Kilowatt-Hours at the Pantograph for the Average October Day for 2,400-Volt D. C. Operation, All Services Combined on the C. & N. W. Ry.

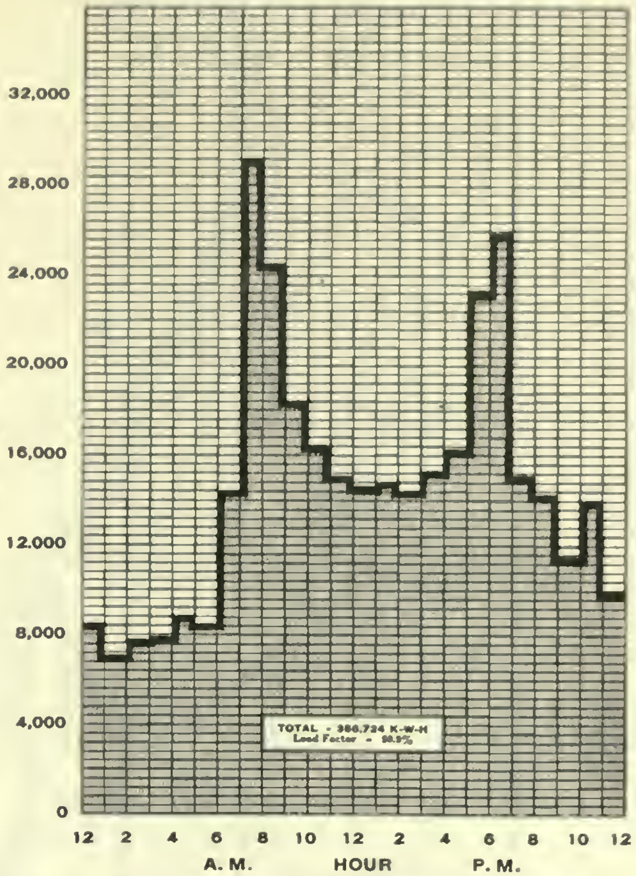


FIG. 622. ENERGY CHART. Kilowatt-Hours Required at the Low Tension Terminals of the Transformers at the Power Station on the Average October Day for 2,400-Volt D. C. Operation. All Services Combined on the C. & N. W. Ry.

CHICAGO & NORTH WESTERN RAILWAY
SUBSTATION AND POWER-STATION LOADS, 600-VOLT D. C.

Sub-station No.	Kilowatt-Hours		Load Factor Per Cent
	Average Hour	Maximum Hour	
1	278	571	48.7
2	422	865	48.8
3	486	1,240	39.2
4	514	1,642	31.3
5	650	2,181	29.8
6	336	875	38.4
7	535	1,348	39.7
8	381	547	69.6
9	293	751	39.0
10	659	1,207	54.6
11	4,280	5,847	73.2
12	2,050	2,638	77.7
13	2,830	6,886	41.1
14	738	2,795	26.4
Power station	15,136	29,137	51.9

Note: Substation loads are at high tension terminals of step-down transformers.

Power-station loads are at low tension terminals of step-up transformers.

FIG. 623. LOCATIONS OF POWER STATION AND SUBSTATIONS FOR THE CHICAGO & NORTH WESTERN RAILWAY FOR THE 600-VOLT D. C. SYSTEM

CHICAGO & NORTH WESTERN RAILWAY
SUBSTATION AND POWER-STATION LOADS, 2,400-VOLT D. C.

Sub-station No.	Kilowatt-Hours		Load Factor Per Cent
	Average Hour	Maximum Hour	
1	1,285	2,787	46.1
2	1,370	4,708	29.1
3	3,420	8,085	42.3
4	6,130	8,646	70.9
5	1,565	2,898	54.0
6	600	1,538	39.0
Power station	14,864	29,209	50.9

Note: Substation loads are at high tension terminals of step-down transformers.

Power-station loads are at low tension terminals of step-up transformers.

FIG. 624. LOCATIONS OF POWER STATION AND SUBSTATIONS FOR THE CHICAGO & NORTH WESTERN RAILWAY FOR THE 2,400-VOLT D. C. SYSTEM

CHICAGO & NORTH WESTERN RAILWAY
SUBSTATION AND POWER-STATION LOADS, 11,000 VOLTS—SINGLE PHASE A. C. SYSTEM

Sub-station No.	Kilowatt-Hours		Load Factor Per Cent
	Average Hour	Maximum Hour	
1	240	491	48.9
2	564	1,237	45.6
3	616	1,872	32.9
4	936	3,228	29.0
5	2,800	6,715	41.7
6	2,160	3,008	71.8
7	3.090	4,239	72.9
8	662	1,332	49.7
9	1,620	3,146	51.5
10	393	1,016	38.7
Power station	13,668	25,928	52.7

FIG. 625. LOCATIONS OF POWER STATION AND SUBSTATIONS FOR THE CHICAGO & NORTH WESTERN RAILWAY FOR THE 11,000-VOLT A. C. SYSTEM

212. GENERAL CONSIDERATIONS UNDERLYING ESTIMATES OF COST

SYNOPSIS: This chapter defines the procedure followed in making up estimates of the cost of electrification, with reference to the choice of electric systems dealt with, and the program of construction to be observed, and with reference also to all allowances and factors of extension, such as those to cover contingencies, growth, interest during construction and cost of trial running.

212.01 Basis of Estimates: The facts presented in the preceding chapters contribute to the development of certain general conceptions affecting the basis of the estimates of cost. The conclusions of some of these define in part the subsequent procedure. There remain to be presented certain general considerations which are necessary to complete the definition of the basis upon which estimates of cost have been developed.

212.02 Electric Systems: Detailed estimates of cost covering all trackage embraced by the Committee's plan of electrification as defined in chapter 209, and that part of the traffic (chapter 202), which is confined to this trackage (chapter 211), have been made for the overhead contact system with 2,400-volt direct current and with 11,000-volt single-phase alternating current.

Estimates of cost have also been made covering the electrification of a single road* by the third rail system with 600-volt direct current, as well as by the overhead contact system with 2,400-volt direct current and with 11,000-volt alternating current. From the relation found to exist between the total costs of electrification of this one road by the third rail system and by the overhead contact systems, considered in connection with the total costs of electrification of all the terminals as developed for the overhead contact system, an estimate of the total cost of electrification of all the terminals by the 600-volt third rail system has been obtained. This procedure has given in effect the total cost of electrification by three different systems:

1. Third rail direct current, 600 volts.
2. Overhead contact direct current, 2,400 volts.
3. Overhead contact alternating current, 11,000 volts.

212.03 Estimates of Cost Based upon an Assumed Procedure Embracing the Entire Terminal: The questions of design, construction and installation as related to the electrification of Chicago's terminals have been developed as a single problem. The trackage included in the plan of electrification having been determined, it has been assumed that the work would proceed under a single administration regardless of the ownership of tracks. One result of this process has been to supply a procedure leading to minimum estimates of cost. For example, in determining power station requirements it has been assumed that a single station for the generation of electric energy will serve all roads alike, rather than that different generating centers of smaller capacity will be supplied for individual roads.

The adoption of this plan does not necessarily imply that, if the railroads of Chicago were to proceed with electrification, they would all join in their efforts to bring about such a result. Whether they would do so or not would constitute a matter of business expediency. In the absence of complicating factors, however, such a procedure, as contrasted with one involving the installation of separate facilities for individual roads, would contribute to economy. The purpose of the Committee in this matter has been to determine the cost to the roads of electrifying the terminals as a whole, and it has assumed for this purpose that electrification, if entered upon, would proceed by methods involving the highest efficiency. Electrification of individual roads, were it to proceed under the auspices of individual roads, would undoubtedly involve much larger expenditures than those which are hereinafter set forth.

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* Chicago & North Western Railway.

212.04 Program of Construction: The Committee's detailed analyses underlying the estimates of the cost of labor and material are based upon statistics for the year 1912. Since the extent of trackage and the volume of traffic are increasing each year, it is evident that the actual cost will depend to some extent upon the period which may elapse between the Committee's statistical year and the beginning of construction. Costs will be influenced also by the duration of the construction period. To meet requirements which are thus imposed, a program of construction has been assumed which specifies that actual work in equipping for electrification will begin in December, 1916, and will end in December, 1922. This program allows six years as a period of construction, which is assumed to be the minimum in which the work could be accomplished. This interval must provide for:

1. A period of preliminary work for the determination of methods and for organization.
2. A period during which actual designs may be developed.
3. A period of construction during which the work is to be advanced as rapidly as its extensive character will permit.

The introduction of this program is not intended to express the opinion of the Committee that the adoption of it is imminent or necessary; it is introduced merely for the purpose of supplying a basis for a definite procedure in the development of estimates of cost which cannot otherwise be fixed.

In the development of estimates of costs, the values of materials and labor necessary to meet conditions prevailing for the Committee's statistical year (1912) have first been set forth. This done, the estimates have been increased to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, as controlled by the program of construction hereinbefore defined.

212.05 Allowance to Cover Growth: The rate at which Chicago's railroad trackage and traffic are increasing is set forth in detail by chapter 203, the conclusions of which constitute the basis of the allowance made for growth.

In apportioning the total cost of electrification to the individual railroads involved, the rate of growth determined for the whole terminal is applied to the individual roads, although it is known that this is not in strict accord with the facts.

The precise value used in extending the estimates covering each of the several details entering into the whole fabric of electrification, is given in connection with each individual study. It will be of interest in this connection to note that certain items entering into the estimates of cost represent phases of the work which cannot be completed until the construction period is ended. The estimates provide for the continued growth of such items up to the time when complete electric operation is to begin, namely, the end of the year 1922.

Other aspects of the work, such as changes in the existing establishment required to accommodate the devices of electrification, may be assumed to be unaffected by the growth of the terminal after electrification has once been determined upon. So long as the terminal is looked upon as a steam operated terminal, structures will be built which serve only to accommodate steam locomotives and their trains; the development will continue without much regard to the requirements of electrification, and consequently the occasions for change, which will appear when electrification is once entered upon, will increase each year. All such increase, however, should cease when the date of the initial work of electrification is once determined; this date, under the program governing these estimates, is December 31, 1916.

212.06 Contingencies: This item is designed to cover incidental expenditures which may arise from sources the significance of which it is difficult to anticipate, and costs arising from exceptional or unexpected causes. Much of the work incident to electrification is indefinite in character, and any estimate based upon actual schedules of material and labor must be a minimum estimate. For example, in determining the cost of the overhead contact system it has been necessary to assume that the supports for the overhead structures will be placed on railroad property. Certain of the more congested districts have been carefully examined in order that the limitations applying in this matter may be known, but it has been impossible to examine minutely all of the routes to be electrified except as these are found in the drawings of the railroad companies. Experience shows that such drawings are often incomplete and that an attempt to erect structures designed on the basis of the information thus made available is certain to involve increased costs due to the presence of obstructions not shown on the maps, or to other conditions which make details in a contemplated program impracticable; that is, the actual cost of such work is necessarily in excess of the cost which is estimated from such drawings. Experience shows also that the cost of labor, in all grades of service, has increased year by year, and it is reasonable to expect that such costs will continue to increase. Many of the items in the estimates which follow include direct labor charges, all of which will be thus affected. The basis of the estimates covering labor is to be found in conditions prevailing during the year 1912. No attempt has been made to extend the estimates thus established to include increases in labor costs up to the end of the year 1922, it being assumed that the increase will be covered by the allowance for contingencies. These conditions, involving uncertainties in the extent of work to be performed and in labor costs, apply to almost every phase of the construction which must proceed along the right-of-way of railroad lines, and for all such work, therefore, the estimates of cost include a contingency allowance of 20 per cent.

For other work of construction, such as that of the power station and power station equipment, substations, locomotives and cars, the design and construction of which can proceed with greater certainty, the contingency allowance has been fixed at 10 per cent.

212.07 Engineering, Design, Supervision and Administration: The fact is recognized that the allowance for engineering may properly be differentiated for the several major items. The engineering costs arising from such work as the contact system, which is complex and requires much individual attention, will be larger than those for locomotives, for which the expenditures are heavy and duplication of machines of a single design may be extensive. It is reported that a large project in steam railroad electrification recently completed provided 12 per cent for engineering, design, supervision and administration; that in the actual working out of this project the cost to the engineering company performing the service was something more than 8.0 per cent, leaving as profits to the company a margin of between 3.0 and 4.0 per cent, which is not to be considered excessive.

If the several roads concerned in the electrification of Chicago's railroad terminals were to undertake separately the development of their individual problems, a flat charge of 10 or perhaps 12 per cent, covering all phases of the work, would not be too much for engineering. It will be remembered, however, that the Committee's assumption underlying all estimates of cost is to the effect that electrification will be developed as a single problem; that the engineering problems when once solved will apply to very large expenditures, a fact which justifies the adoption of a minimum allowance to cover engineering, design, supervision and administration.

In accordance with this view, the estimates of cost provide an allowance of 10 per cent for engineering on all portions of the work except electric locomotives, multiple-unit cars and trailers. For these an allowance of 5.0 per cent is applied.

212.08 Interest, Insurance and Taxes during Construction: A logical basis upon which to determine the value of the allowance which should be made for interest, insurance and taxes during construction might be supplied by the development of a detailed estimate of progress for the entire period of construction. This progressive plan could be made to show the rate at which money would be invested and the rate at which equipment and other facilities purchased would become available for service. On the basis of such a program, in combination with accepted rates, a logical allowance for this factor could be determined. The fact remains, however, that any such program would necessarily be more or less a speculative one and the resulting allowance would probably possess no higher degree of reliability than would a flat rate applied to the total expenditure and the entire period of construction. Experience shows that a flat rate of approximately two per cent per annum for the entire period is entirely justified in work similar to that contemplated. In the development of so extensive an electrification project as that presented by the Chicago railroad terminals, costs under this head could doubtless be somewhat reduced by a systematic and progressive development of the work, which would permit parts of the whole system to come into effective operation at intervals throughout the period of construction. It would not be necessary to delay the electric operation of a certain yard or of an individual railroad terminal until all yards and all terminals could be equipped; and in view of the great diversity of trackage and of operating conditions presented by the Chicago terminals, it is reasonable to suppose that a minimum charge would suffice.

In view of these considerations, the Committee's estimates of cost include an allowance for interest, insurance and taxes during construction, of 1.75 per cent per annum applied to the total cost and to the whole period of construction.

212.09 Summary of Allowances and Extensions: The following statement summarizes the conclusions set forth in the preceding sections and defines in detail the several allowances and extensions which have been employed in making up the estimates of costs and values.

1. Work of uncertain extent which must continue to the completion of the whole scheme, including contact system, transmission lines, facilities necessary to overcome inductive effects, bonding, new steam locomotive terminals and telephone patrol lines. These are subject to the following allowances:

	PER CENT
a. Extensions to cover growth from December 31, 1912, to December 31, 1922:	
1. Contact system, transmission lines, facilities necessary to overcome inductive effects, bonding and new steam locomotive terminals	30.0
2. Telephone patrol lines	10.0
b. Contingencies	20.0
c. Engineering, design, supervision and administration	10.0
d. Interest, insurance and taxes during construction, 1.75 per cent per annum, for 6 years	10.5

2. Work of uncertain extent, the further development of which may properly be assumed to cease when electrification is once determined upon, including transfer of machinery to new locations, bridge warnings and changes in overhead structures, wire lines and signal systems. For these the following allowances are made:

	PER CENT
a. Extensions to cover growth from December 31, 1912, to December 31, 1916:	
1. Transferring machinery to new locations, bridge warnings, changes in overhead structures and wire lines	12.0
2. Changes in signal systems	20.0
b. Contingencies	20.0
c. Engineering, design, supervision and administration	10.0
d. Interest, insurance and taxes during construction, 1.75 per cent per annum, for 6 years	10.5

3. Work of rather definite character which will continue to the completion of the period of construction, including power station and equipment, substations and equipment, switching stations, locomotives and cars. For these the allowances will be as follows:

	PER CENT
a. Extensions to cover growth from December 31, 1912, to December 31, 1922, based upon increase in energy requirements as determined from the estimated growth of traffic	30.0
b. Contingencies	10.0
c. Engineering, design, supervision and administration:	
1. Power station and substation buildings and equipment	10.0
2. Locomotives, cars, work and inspection equipment	5.0
d. Interest, insurance and taxes during construction, 1.75 per cent per annum, for 6 years	10.5

4. Values of terminal facilities to be abandoned and of steam rolling equipment to be released as determined for 1912. These are subject to an extension to cover growth only, as follows:

	PER CENT
a. For terminal facilities to be abandoned, to cover growth for 4 years from 1912 to 1916, at 3 per cent per annum	12.0
b. For steam rolling equipment to be released, to cover growth for 7 years from 1912 to 1919, at 3 per cent per annum	21.0

212.10 Land: Except in the case of land as a site for a central power station and of land for transfer yards, it has been assumed that there will be neither cost nor credit arising from transfers of real estate.

The removal of steam locomotive terminals from the territory to be electrified makes available certain areas which may be sold or put to other uses by the railroad companies owning them; on the other hand, the necessity for establishing substations, inspection sheds for locomotives and multiple-unit equipment, and other structures incident to electric operation will require land which in many cases is not now available. While transfers of land will necessarily be involved in any large scheme of electrification, it has been assumed that the credits will equal the debits and that in determining costs no account need be made of such transactions. As already noted, exceptions are made in the case of land for a central electric power generating station and in that of land which will be required for the establishment of transfer yards at the termini of the electrified trackage.

212.11 **Cost of Interference with Traffic:** The process of developing extensive betterments along the right-of-way of railroads must proceed in such a manner as to avoid interference with traffic; or, if traffic is to be subject to delay, the increased operating costs resulting from such delay should constitute a charge against the costs of the betterment. In the development of these estimates it is assumed that traffic movements will not be materially hindered and that the entire burden of cost imposed by local conditions will be borne by the work under construction.

212.12 **Trial Running:** Experience has shown that, as a preliminary to the regular operation of any considerable electric railroad system, time must be taken in which to train employes in the handling of new equipment and in which to perfect all the various details incident to the new procedure. The process is one which involves the constant movement of equipment under prospective schedules without revenue passengers or freight. The duration of this experimental period of operation will depend upon the magnitude and complexity of the operations involved, and its cost must stand as a charge against electrification. In the development of the estimates which follow, no separate item has been entered to cover the cost of preliminary or experimental operation, since it is assumed that the contingency factor will cover this item.

212.13 **Changes in the Existing Facilities:** The estimates are designed to cover all changes in the existing railroad facilities necessary to the admission of electric operation. In providing for such changes it has been assumed that facilities affected will be replaced in kind; that if the necessity for a change is made the occasion for introducing a substantial betterment to an existing facility, the cost of the betterment will not constitute a charge against electrification. For example, the estimates provide for the reconstruction of all existing signals to make them operative in the presence of the traction currents incident to electric operation. It is probable that a road having signals which are old or unsatisfactorily located may object to the reconstruction of its old system on the ground that it will be better policy to provide an entirely new installation of signals. New signals, however, would constitute a material betterment in an existing facility, and that portion of the cost in excess of the cost of changing existing signals is not regarded as a proper charge against electrification. Again, a road having insufficient facilities for the accommodation of steam locomotives within the city will, in removing such facilities to points outside the city, be inclined to create upon the new site a much better establishment than it abandons. While the estimates recognize a certain degree of freedom in the development of such matters, the principle which has controlled requires the re-established facility to respond to the standards which characterize the facility abandoned. To do more than this would involve providing a steam facility betterment at the expense of electrification.

212.14 **Responsibility for Changes:** In presenting the costs of changes to overhead structures and wire lines (sections 213.073 to 213.080), no attempt has been made to segregate by ownership the costs of the facilities requiring the change. All such costs are a necessary part of the cost of electrification, but nothing in this presentation should be construed as indicating the degree to which the railroads are responsible for the costs of such changes.

212.15 **Ownership of Tracks:** The trackage to be electrified includes a considerable mileage (6.7 per cent of the total) owned by industries. In determining those factors of the cost of electrification which are direct functions of the trackage involved, such as the contact system, bridge warnings and return circuit, the cost for the different classes of track on the basis of conditions existing in 1912 has been determined separately. From these segregations, the relative cost of equipping privately owned tracks may be noted.

This apportionment, however, has not been carried forward in the accounting. The costs, as presented in the several summaries, do not differentiate between the cost of equipping privately owned tracks and that of equipping those owned by railroads.

212.16 Significance of Any Basis Governing Costs: Any basis governing estimates of costs constitutes, in effect, a specification of work to be done and of the manner in which it is to be done. The specifications of this chapter and of those immediately preceding constitute such a basis.

The process of developing this basis has involved the settlement of many debatable questions. In arriving at its conclusion, the Committee has necessarily been controlled by certain fundamental conceptions the significance of which has been fully discussed. With reference to details, the Committee also has sought, as a basis for its decisions, to secure the fullest information possible covering conditions peculiar to individual roads. Notwithstanding the care that has been taken, it is unlikely that all the decisions are such as would have been reached by the officers of the roads involved. If electrification is to proceed, individual interests will operate to introduce modifications in the extent of the undertaking and in the procedure by which it is put into effect. The introduction of any modification will probably affect costs.

The fact which it is sought to emphasize concerns the dependence of the estimates which follow upon the basis which is herein set forth. Such estimates can be of value only in so far as the basis upon which they have been developed is approved and accepted by those who control the properties affected.

212.17 Cost of Electrification Not a Complete Measure of the Investment which must be Made: Experience has shown that the development of any considerable undertaking designed to improve the character of an existing facility opens the way for, or must be preceded by, other changes. The electrification of the railroad terminals of Chicago constitutes an expensive improvement. It should not be undertaken until all necessary changes in the existing facilities, though not immediately in prospect, shall have been made. For example, a railroad possessing a complicated arrangement of tracks which might be simplified will find it desirable to correct the obvious fault as a preliminary to the electrification of its tracks. The railroad terminals of Chicago as they now exist have been developed as a result of a process of growth. As a consequence, they present many unsatisfactory conditions which, in the interest of economical operation, will in time be remedied. With electrification in prospect such changes cannot wisely be deferred. They must be made prior to the investment for electrification.

A discussion of these precipitated costs and of those due to departures from the Committee's plans is reserved for later presentation (sections 213.110 to 213.116). The present purpose is to define them and to make clear the fact that the basis of estimates does not provide for them. Their omission from the Committee's accounting obviously cannot operate to protect the railroad companies from the investment which they will entail, and as a consequence the additions to capital which will attend the process of electrification will be in excess of the cost of electrification as hereinafter set forth.

213. THE ESTIMATED COST OF COMPLETE ELECTRIFICATION

SYNOPSIS: This chapter presents the Committee's estimates of the cost of equipping the Chicago railroad terminals for electric operation. The direct cost of electrification includes the cost of new facilities and of changes in existing facilities made necessary by the proposed change from steam to electric operation. Other costs, such as those arising from departures from the Committee's plan or such as may be precipitated by electrification, are discussed. The estimates cover three systems of electric traction, namely, 11,000-volt alternating current overhead contact, 2,400-volt direct current overhead contact and 600-volt direct current third rail contact. Those for the two overhead contact systems are presented in detail for the entire terminal; those for the third rail system are presented for a single road only, but in such form as to supply the basis upon which the cost of third rail electrification for the entire terminal is determined.

213.001 Scope of the Estimates: The basis of the Committee's estimates of cost has already been presented (chapter 212). The complete estimates of the cost of electrification as thus established may now be set forth. They include the cost of power station, transmission system, substations, contact system, electric rolling equipment and all other elements which go to make up the proposed electric establishment as a means in smoke abatement; they include the cost of certain definite changes in existing facilities which are essential to the use of the electric equipment and structures; and they consider also an allowance covering credits which will arise through the release for service elsewhere of equipment now used in Chicago but which after electrification will no longer be needed there. All such items can be evaluated; and their summation (section 213.139) constitutes, for the purposes of this report, the total direct cost of electrification.

The financial burden imposed by electrification is greater than the amount covering direct costs, for the reason that the railroads, in the event electrification is required, will consider their individual interests and will probably depart from the plans formulated by the Committee, developing plans more extensive or proceeding by methods which may prove more costly. Electrification also will precipitate changes and betterments which otherwise might be long deferred. The nature and extent of these departures from and additions to the plans of the Committee will be hereinafter discussed (sections 213.110 to 213.116). The financial burden they will impose will constitute certain indeterminate costs due to electrification. Extending this interpretation, it is apparent also that Chicago's claim to the benefits of electrification are in no way different from those which might be urged by many other cities with which Chicago railroads connect, and that compulsory electrification, if achieved for Chicago, may in due time be secured by all of the larger cities of the country. The cost, therefore, which might be imposed upon the railroads as a whole by the compulsory electrification of Chicago's railroad terminals would be a small fraction of the total expense which might ultimately be imposed upon the railroads.

The present purpose will be served if the fact is made clear that the estimates of direct cost which follow cover only those details which are provided for in the plans. They are not a complete measure of the financial burden which electrification will impose.

THE DIRECT COST OF ELECTRIFICATION

213.002 Direct Cost of Electrification: As a matter of convenience in developing the estimates of cost, the whole problem of electrification has been divided into a series of studies, each one of which has been developed separately for direct current and for alternating current overhead contact systems. The problem of electrification by a direct current third rail system has been developed for a single road, and results thus obtained have been extended to cover the entire terminal. The subjects of the several studies are:

1. Power station.
2. Transmission system.
3. Substations.
4. Switching stations.
5. Overhead contact system.
6. Bridge warnings.
7. Return circuit.
8. Prevention of inductive effects and electrolysis.
9. Telephone system.
10. Electric locomotives, multiple-unit equipment, work and inspection equipment.
11. Spare parts.
12. Alterations to bridges and buildings.
13. Changes in wire lines.
14. Changes in signal systems.
15. Removal and re-establishment of steam locomotive terminals.
16. Rolling equipment released.
17. The estimated cost of electrification by systems.
18. A summary of direct costs.

Each one of the studies concludes with an estimate of cost (or credit) segregated by roads. The basis employed for the segregation in each case is either evident or stated.

POWER STATION

213.003 General Considerations: The electric power required to operate the railroad terminals of Chicago may be secured in several different ways. Reference has been made (section 208.08) to the possibility of securing it by purchase. It is the present purpose to present the results of a study of installation costs based upon the premise that the railroads will provide their own source of power.

While the amount of power to be generated is sufficient to justify the establishment of two or more stations, providing other considerations make such a procedure desirable, experience elsewhere has shown that single power stations, if of large capacity, can be made entirely reliable as a source of uninterrupted power. There are, moreover, certain minor advantages affecting both first cost and operating expenses which are favorable to the choice of a single generating station rather than of two or more stations, the combined capacity of which will equal that of the single station.

The location of any large power station must be determined with reference to the work to be done. Transmission problems are simplified if the source of power can be near the point or points of power consumption. A power station, also, must be near an abundant supply of water, and its location must permit of the development of transportation facilities to serve in the handling of fuel and ash.

These related questions, as they apply to the problem of developing a source of power which will serve in the operation of the railroads of Chicago, have all been carefully studied. The conclusion has been reached, that a single power station, located near the south branch of the Chicago River in the vicinity of Ashland Avenue, would satisfactorily meet all requirements. The load center of the power requirements, under the plan of electrification as already defined, falls within the limits of the Union Stock Yards. The location indicated is not far removed from this point and is such as satisfies other requirements of the problem.

213.004 Station Characteristics and Load: It has been assumed that the particular site which will be selected will be fairly level, and that the nature of the soil will be such as to require all building and machine foundations to be carried on piles of from 30 to 40 feet in length. Proceeding from these assumptions, a power station has been laid out providing for a steam turbine room with a gallery along one side to accommodate the switching requirements of the plant, the step-up transformers and the substation apparatus. The boiler room is on the side opposite this gallery.

The boiler section of the plant provides for boilers on two floors, with pumps and other facilities at the ground level below. The boilers are arranged with firing aisles at right angles to the turbine room, there being four such aisles and three 250-foot chimneys. Estimates have been based upon the use of water-tube boilers of 650-horse-power capacity each, equipped with automatic stokers capable of operating the boilers at a rating of from 200 to 240 per cent of normal rating, the peak loads requiring operation at a rating of 200 per cent. Coal bunker capacity provides for two weeks' supply, and the plant is equipped with all necessary coal conveying, elevating and crushing machinery for receiving coal by rail or by water.

The turbine room will accommodate seven steam turbine generating units. Each turbine is of the single unit type operated at 1,500 revolutions per minute. The turbines will exhaust into condensers, the cooling water for which will be taken from and discharged into suitable tunnels running the length of the turbine room and terminating at the waterfront, where suitable gates and screens will be provided on the intake side.

The generators are to be of the 11,000-volt, three-phase type. The transformers will raise the generator voltage to 33,000 volts. The switching, both at 11,000 volts and 33,000 volts, will be accomplished by means of high capacity oil switches, those for the feeders to be of the reactance type.

The details of the power station design for both the 2,400-volt direct current and the 11,000-volt alternating current systems of traction are the same in all essential characteristics affecting design and arrangement of parts, the only difference being that the 33,000-volt secondaries of the transformers are to be connected three-phase for the direct current system and two-phase for the alternating current system. For the former the transmission will be three-phase, and for the latter single-phase but with feeders so grouped that the load will approximately be divided equally between the two phases of the transformers. It is believed that, with the large and diversified train movements to be handled, this arrangement will insure a practical balancing of the load on the three phases of the generator.

For the direct current system the average power station load for the maximum hour is approximately 125,000 kilowatts, with an estimated power factor of 95 per cent, and for the alternating current system the load is approximately 8 per cent less, or 115,000 kilowatts, with an estimated power factor of 70 per cent. This difference of 8 per cent in the output of the station, assuming the use of the 2,400-volt direct current system or that of the 11,000-volt alternating current system, is not sufficient to justify a difference in the kilowatt rating of the generator units installed. Estimates are therefore based upon the assumption that seven 20,000-kilowatt steam turbine generating sets will be required in both plants, or an installed capacity of 140,000 kilowatts, based on the usual maximum continuous rating. This allows the plant, assuming the use of either system, one spare unit. In the boiler plant, however, where the total power is made up of a large number of comparatively small units, the capacity of the units has been adjusted to the load requirements with proper allowance for spares in both cases. The power station characteristics and load, assuming the use of the 2,400-volt direct current system of traction and also that of the 11,000-volt alternating current system of traction, are set forth by table CCLVIII.

TABLE CCLVIII. POWER STATION CHARACTERISTICS AND LOAD
(Basis of 1912)

Item	2,400-Volt D. C. System	11,000-Volt A. C. System
Peak load, one hour, kw.	125,700	114,600
Estimated power factor of load, per cent	95	70
Load factor, per cent	62.5	64.2
Output per day, kw-hr.	1,886,600	1,765,200
Output per year, kw-hr.	690,495,600	646,063,200
Number of generator units installed	7	7
One hour continuous capacity of unit, kw.	20,000	20,000
Maximum overload capacity, kw. per unit	27,000	27,000
Rating of six units in service on maximum load, kw.	120,000	120,000
Loading of generators during maximum hour, per cent	105	96
Total installed capacity, kw.	140,000	140,000
Installed capacity of step-up transformers, kv-a.	96,000	112,000
Maximum capacity of transformers for five minutes, per cent overload	200	200

213.005 Estimates of Costs of Power Station on the Basis of the Requirements of 1912, Excluding all Allowances for Contingencies and for Engineering: Based upon the lay-out of the plant already described and upon facts otherwise available, an estimate has been made of the costs of the power station as designed to serve a 2,400-volt direct current system of traction, and also of a similar station designed to serve a 11,000-volt alternating current system. The estimates of costs, excluding all allowances for contingencies and for engineering, are shown by table CCLIX.

TABLE CCLIX. ESTIMATED COSTS OF POWER STATION, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING
(Basis of 1912)

Item	2,400-Volt D. C. System	11,000-Volt A. C. System
Real estate, foundations, intake and discharge tunnels and building complete	$1,931,000	$1,931,000
Boilers, stokers, pumps, piping, flues, chimneys, coal and ash handling plant, and other boiler plant accessories	1,680,000	1,571,000
Turbine units, condensers, switchboards, exciters, step-up transformers, crane, and other turbine room accessories	2,265,000	2,425,000
Totals	$5,876,000	$5,927,000

It is of interest to note that the costs shown by these estimates, as based upon an installed capacity of 140,000 kilowatts, are $41.97 and $42.34 per kilowatt, respectively. The amount is substantially the same for both systems. If an amount of 10 per cent is added for contingencies and 10 per cent for engineering, the cost becomes approximately $50.00 in both cases. Such additions are, however, matters for which provision is hereinafter made. It should be noted that in arriving at a kilowatt cost the same rating is assumed for both plants, notwithstanding the fact that there is less boiler capacity in the plant designed to serve the alternating current than in that designed to serve the direct current system.

213.006 Estimated Total Cost of Power Station: The estimated total cost of the power station for the electric operation of the Chicago railroad terminals is based upon the cost of labor and materials as determined for the year 1912, extended in a manner normal to these estimates (chapter 212), the factors of extension in this case being as follows:

	PER CENT
1. To cover growth in traffic and mileage of railroads, December 31, 1912, to December 31, 1922 . . .	30.0
2. Contingencies	10.0
3 Engineering, design, supervision and administration	10.0
4. Interest, insurance and taxes during construction, 1.75 per cent per annum, for 6 years, December 31, 1916, to December 31, 1922	10.5

The values thus derived may be accepted as the total cost on the basis of the requirements of 1922. This cost has been divided among the several railroads to be served, on the basis of the energy requirements for the maximum hour.

The estimated total cost, by railroads, of the power station, including real estate, building and equipment, is set forth for both the 2,400-volt direct current system and the 11,000-volt alternating current system by table CCLX.

The fact should be emphasized that the power station costs as exhibited by railroads in table CCLX merely represent the share of the several roads in the cost of a single station designed to serve all alike. If, in the actual development of electrification, the individual roads should prefer to provide individual power stations, the costs would be in excess of those set forth. The increase, especially for the smaller roads, would be material.

TABLE CCLX. ESTIMATED TOTAL COST OF POWER STATION INCLUDING REAL ESTATE, BUILDING AND EQUIPMENT, BY ROADS

(Dec. 31, 1922)

Railroad	2,400-Volt D. C.	11,000-Volt A. C.
Atchison, Topeka & Santa Fe Ry.	$ 123,583	$ 124,655
Baltimore & Ohio R. R.	150.138	151,441
Baltimore & Ohio Chicago Terminal R. R.	193,034	194,710
Calumet, Hammond & Southeastern R. R.	14,299	14,423
Chesapeake & Ohio Ry. of Indiana	32,683	32,967
Chicago & Alton R. R.	148,095	149,381
Chicago & Calumet River R. R.	13.277	13,393
Chicago & Eastern Illinois R. R.	176,693	178,226
Chicago & Erie R. R.	82,729	83,447
Chicago & North Western Ry.	2,191,808	2,210,831
Chicago & Western Indiana R. R. and the Belt Railway of Chicago	646,512	652,123
Chicago, Burlington & Quincy R R.	604,637	609,885
Chicago Great Western R. R.	82,729	83,447
Chicago, Indiana & Southern R. R.	62,302	62,843
Chicago, Indianapolis & Louisville Ry.	98,049	98,900
Chicago Junction Railway	256.358	258,583
Chicago, Milwaukee & St. Paul Ry.	758,860	765,445
Chicago River & Indiana R. R.*	....	....
Chicago, Rock Island & Pacific Ry.	563.783	568,676
Chicago Short Line Ry.	12,256	12,363
Chicago Union Transfer Ry.†	....	....
Chicago, West Pullman & Southern R. R.	39,832	40,178
Elgin, Joliet & Eastern Ry.	235,931	237,979
Grand Trunk Western Ry.	131,754	132,897
Illinois Central R. R.	1,124,502	1,134,261
Illinois Northern Ry.	26,555	26,785
Indiana Harbor Belt R. R.	83,750	84,477
Lake Shore & Michigan Southern Ry.	675,110	680,969
Michigan Central R. R.	222,653	224,586
Minneapolis, St. Paul & Sault Ste. Marie Ry.	56,174	56,662
New York, Chicago & St. Louis R. R.	125,626	126,716
Pere Marquette R. R.	101,113	101,991
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	313,553	316,275
Pittsburgh, Fort Wayne & Chicago Ry.	604,637	609,885
Pullman Railroad	23,491	23,695
Wabash Railroad	236,952	239,009
Totals	$10,213,458	$10,302,104

* Included in the estimates for the Chicago Junction Railway.

† Included in the estimates for the Chicago & Western Indiana Railroad.

TRANSMISSION SYSTEM

213.007 General Considerations: With both the 2,400-volt direct current system and the 11,000-volt alternating current system, transmission lines will be required for the distribution of power from the power station to substations located throughout the electrified district. Estimates of the cost of the transmission systems required are based upon the following general specifications:

1. 33,000 volts on all circuits.
2. Duplicate circuits between the power station and all substations.
3. Interconnection of substations with transmission lines to a reasonable extent.
4. Overhead open wire construction located on the rights-of-way of the railroads.
5. Three-phase circuits for the 2,400-volt system and single-phase circuits for the 11,000-volt system.
6. Supporting the transmission conductors on the structures of the contact system.

213.008 Character of Transmission Circuits: The efficiency of a transmission system may be developed to almost any desired limit by providing sufficient conductor material. The designs selected for the basis of the estimates provide high efficiency of transmission with reasonable economy of material. It has been considered desirable, in order to secure adequate mechanical strength, to limit the minimum size of any conductor to No. 1 A. W. G. copper cable. The required sizes for transmission wires were determined by assuming the use of circuits of No. 1 wire from the power station to the substations and then combining the several parallel circuits, when desirable, into duplicate circuits of larger wire having practically equivalent combined cross-section. This procedure provides an efficiency of the transmission system of 98.5 per cent for the 2,400-volt direct current system and of 98.1 per cent for the 11,000-volt alternating current system.

The routes and make-up of the transmission circuits are shown for the 2,400-volt direct current system by fig. 626 and for the 11,000-volt alternating current system by fig. 627.

As previously stated, duplicate circuits are to be provided between the power station and each substation. The lay-out also provides, when feasible, for separate routes for these duplicate lines. When duplicate circuits are to be run along the same right-of-way, they are to be carried on opposite sides of the tracks.

The total length and weight of various sizes of wire required in the make-up of the transmission systems for the two overhead contact systems of traction are shown by tables CCLXI and CCLXII.

TABLE CCLXI. TRANSMISSION WIRE REQUIRED FOR THE 2,400-VOLT D. C. SYSTEM
(Basis of 1912)

No. (A. W. G.)	Miles	Pounds
1	307.5	418,889
00	212.0	460,057
000	64.5	176,410
0000	61.5	212,042
Totals	645.5	1,267,398
Add 5 per cent for sag, special crossings, etc.	32.5	63,602
Totals	678.0	1,331,000

TABLE CCLXII. TRANSMISSION WIRE REQUIRED FOR THE 11,000-VOLT A. C. SYSTEM
(Basis of 1912)

No. (A. W. G.)	Miles	Pounds
1	412	552,000
0	46	77,500
00	205	436,000
000	59	158,500
0000	39	132,000
250,000 c. m.	143	583,000
Totals	904	1,939,000
Add 5 per cent for sag, special crossings, etc.	46	97,000
Totals	950	2,036,000

Pin type insulators are to be used for carrying transmission circuits except at such spans as are necessary at stations, streets, grade crossings and dead-ends where strain insulators are to be used.

213.009 Supporting Structures: The steel supporting structures of the overhead contact system are designed for the joint load imposed by the catenary contact construction, by an assumed standard transmission line and by two overhead ground wires (section 213.025). The standard transmission line will consist of 4 No. 1 A. W. G. wires on each of the two extensions to the posts or poles at ends of cross-span. The estimates of cost of contact system therefore include the cost of a considerable amount for steel and concrete chargeable to the transmission system. No attempt is made in the estimates to distribute this amount or to provide credit where the supporting structures do not carry transmission circuits.

On certain sections, where the transmission line imposes a greater load than the assumed standard for which the supporting structures are designed, it is necessary to provide for the cost of heavier structures with larger foundations and special cross-arms. This additional cost is included in the estimates covering the transmission system. The 2,400-volt direct current system and the 11,000-volt alternating current system will require 24.28 miles and 19.75 miles, respectively, of overhead supporting structures in which additional steel and concrete will be necessary to carry the additional transmission line load. The designs for the structures provide for the support of the lowest transmission wire at not less than 37 feet above the top of the rail at the structure. Cross-arms at all supports are to be of sufficient length to furnish a minimum spacing of 5 feet for transmission wires.

Independent supporting structures are to be provided for the transmission lines leaving the power station. Such independent structures are to be provided also at points where the multiplicity of wires requires supports in addition to those which could be suitably arranged on the catenary supporting structures, and where other local conditions make it undesirable to use the structures of the contact system. There are 3.87 miles of this construction required, the route of which extends from the proposed power station south along the Chicago Junction Railway and east and west along the tracks of the same railroad under the structure of the South Side Elevated Railroad. The structures for this type of

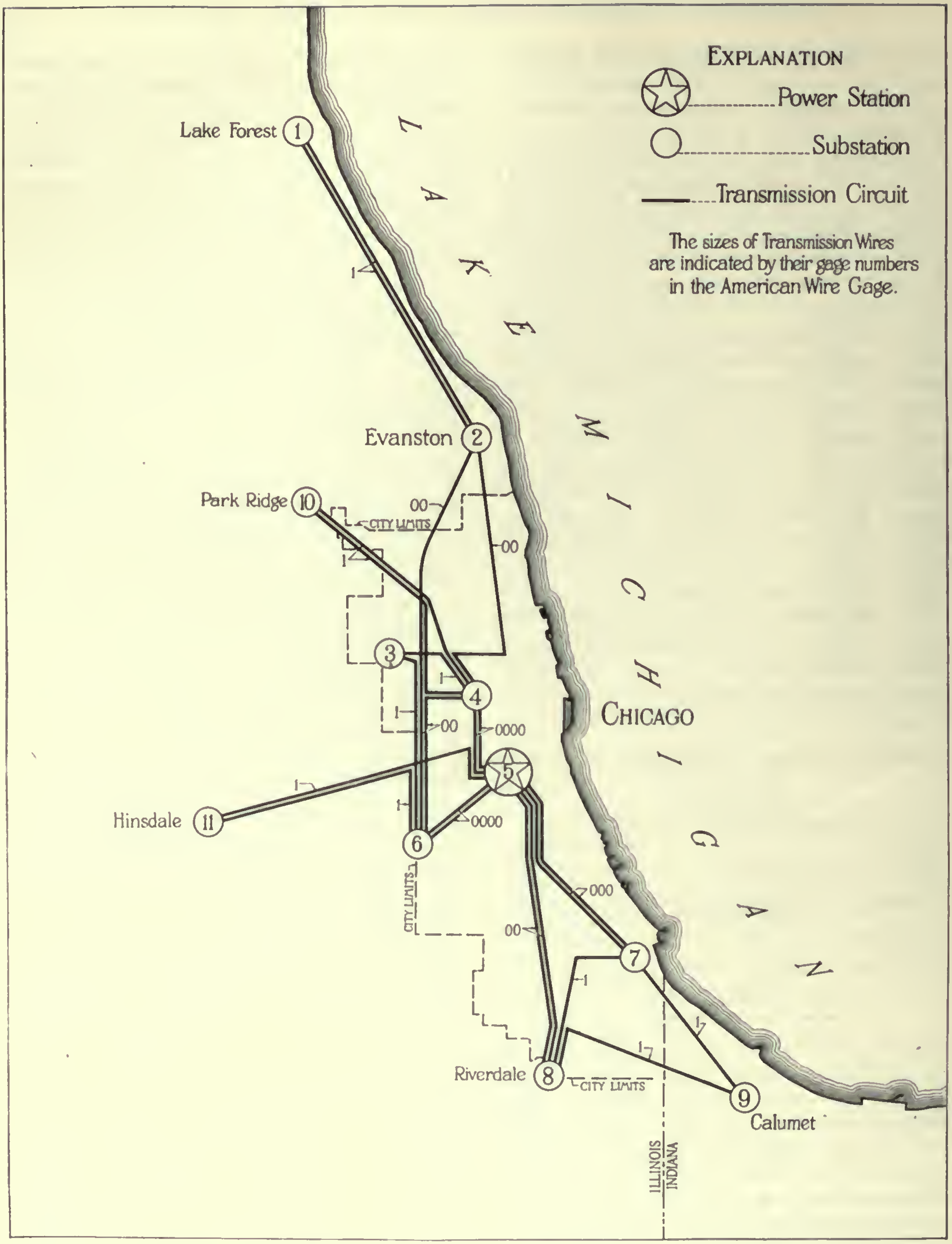
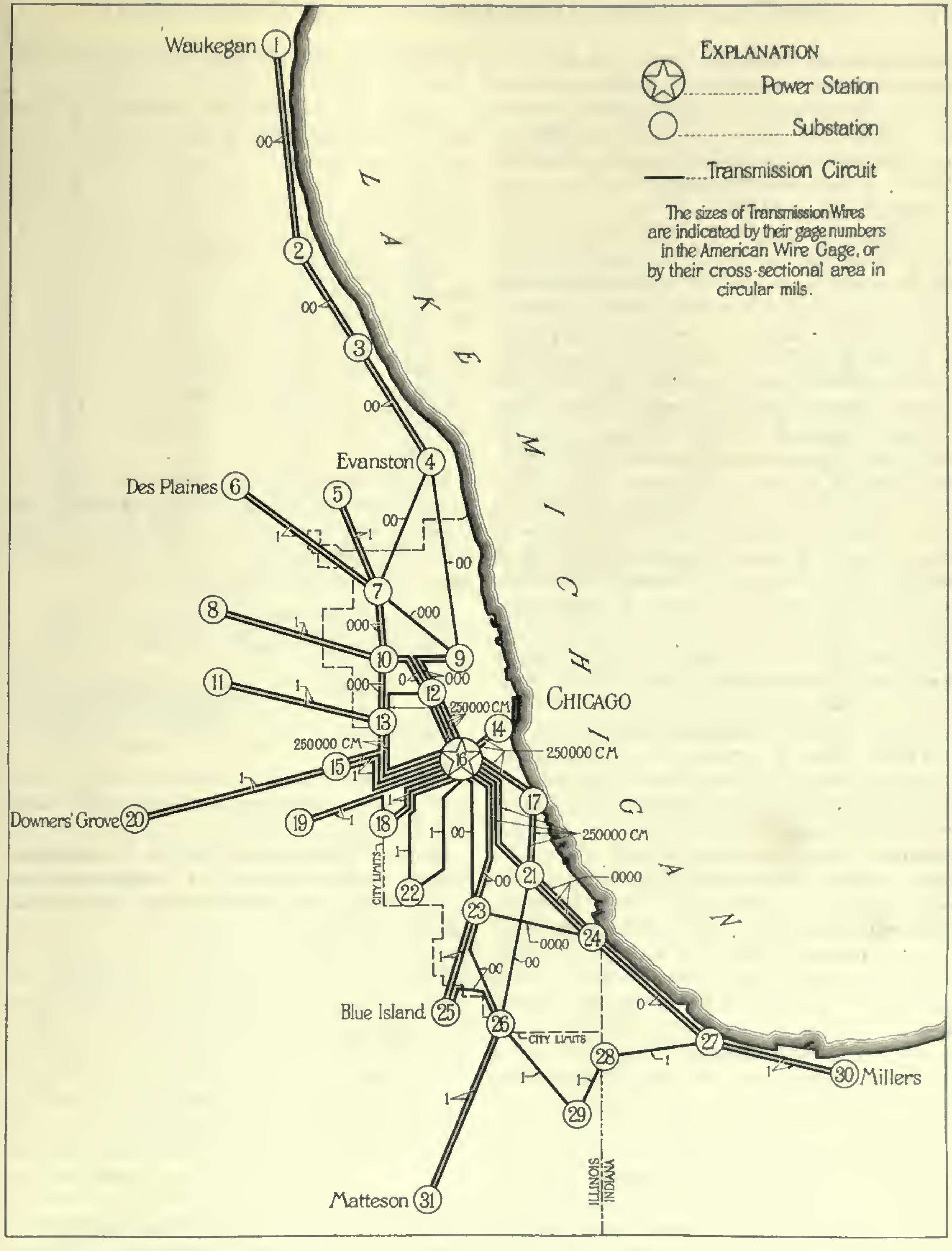


FIG. 626. TRANSMISSION CIRCUITS FOR THE 2,400-VOLT D. C. SYSTEM



The sizes of Transmission Wires are indicated by their gage numbers in the American Wire Gage, or by their cross-sectional area in circular mils.

FIG. 627. TRANSMISSION CIRCUITS FOR THE 11,000-VOLT A. C. SYSTEM

construction are to consist of steel poles with concrete foundations designed for maximum load conditions. Poles are to be spaced at intervals of 300 feet and the lowest wire is to be supported 30 feet above the ground at the pole, which will provide a minimum clearance of 25 feet under maximum sag conditions.

Crossings of transmission lines over navigable waters are to be provided for by the use of steel towers supporting the lowest wire at a minimum clearance of 120 feet above high water. In addition to the transmission wires, these towers are to support ground wires and the necessary trolley feed wires to furnish a continuous conductor for the contact system at these crossings. The structure designed for the preparation of the estimates is approximately 145 feet high, and is supported on concrete foundations. Steel structures and foundations are also necessary at both ends of bridge draws to dead-end the contact wire when the draw is open. There are 29 locations in the electrified zone where provision for river crossings must be made. At many of these points there will be no transmission lines, the towers being provided for the support of the contact conductors only, but the costs of all river crossings have been included as a part of the estimated cost of the transmission lines.

Another type of crossing for which special structures are to be provided for transmission lines will be necessary at points where bridges cross over tracks and do not allow sufficient clearance for the transmission wires. The estimates include the cost of 70-foot steel towers with concrete foundations for such locations. These will provide ample clearance for wires above the obstructions. There will be 19 such crossings for the 2,400-volt direct current system and 25 for the 11,000-volt alternating current system.

213.010 Ground Cables: The ground cables are to be $\frac{3}{8}$-inch, 7-strand, double galvanized Siemens-Martin steel. A ground wire is to be provided on the extensions of each of the posts or poles of catenary supporting structures along main tracks, irrespective of whether or not they are to support transmission circuits. The estimates also provide for grounding the cables at every tenth structure with ground plates and cable. The cost of all ground wire construction is included in the estimates covering the transmission system.

213.011 Unit Costs: The following are the unit costs of material and labor which have been used in the estimates:

	UNIT COST
Base price of copper wire, per lb.	$ 0.1775
Insulator and pin, each	1.00
Strain insulator, each	2.25
Labor for erecting No. 1 and No. 0 cable and insulators, per mile	75.00
Labor for erecting No. 00 to 250,000 cir. mils. cable and insulators, per mile	100.00
Ground cable erected, per mile	145.00
Steel in place with one coat of paint, per lb.	0.04
Concrete in place, per cu. yd.	12.00
Cost of steel and concrete in independent transmission pole line, per mile	5,000.00
Steel towers where bridges cross over tracks, each	300.00

The estimated costs per route mile for the additional concrete and steel required where the standard structures for the contact system are not sufficiently heavy to carry the transmission lines, are shown by table CCLXIII.

TABLE CCLXIII. ESTIMATED COSTS PER ROUTE MILE, OF EXTRA CONCRETE AND STEEL REQUIRED IN STANDARD STRUCTURES TO PROVIDE FOR TRANSMISSION LINES
(Basis of 1912)

System	Main Track	
	Cross Catenary	Structural Steel
2,400-Volt D. C.	$300.00	$750.00
11,000-Volt A. C.	160.00	160.00

The estimated costs of towers and extra bridge steel at river crossings are set forth by table CCLXIV.

213.012 Estimates of Costs of Transmission System on the Basis of the Requirements of 1912, Excluding all Allowances for Contingencies and for Engineering: The costs of the transmission system required for the electric operation of the Chicago railroad terminals, including that of other allied items grouped for convenience under this head as already explained, have been estimated on the basis of the lay-out described. The estimates of costs, excluding all allowances for contingencies and for engineering, for the transmission systems required for the 2,400-volt direct current system and for the 11,000-volt alternating current system, are presented by table CCLXV.

213.013 Estimated Total Cost of Transmission System: The estimated total cost of the transmission system required for the electric operation

TABLE CCLXIV. ESTIMATED COSTS OF TOWERS AND EXTRA BRIDGE STEEL AT RIVER CROSSINGS
(Basis of 1912)

Number	Cost of Concrete and Steel		Total Cost
	Towers	Contact Dead-End	
1	2	3	4
1	$3,228	$1,230	$ 4,458
2	2,758	847	3,605
3	2,758	847	3,605
4	2,758	847	3,605
5	3,228	1,230	4,458
6	3,212	1,230	4,442
7	3,228	1,230	4,458
8	3,228	464	3,692
9	3,212	464	3,676
10	2,758	847	3,605
11	2,758	847	3,605
12	2,666	6,700	9,366
13	2,656	3,252	5,908
14	3,228	464	3,692
15	3,212	464	3,676
16	2,656	3,252	5,908
17	3,228	464	3,692
18	3,228	1,230	4,458
19	6,526	9,980	16,506
20	3,228	1,230	4,458
21	3,228	1,230	4,458
22	2,758	847	3,605
23	3,228	1,230	4,458
24	3,228	464	3,692
25	3,228	464	3,692
26	2,758	847	3,605
27	2,666	3,609	6,275
28	3,228	464	3,692
29	2,666	7,984	10,650
Totals	$90,742	$54,258	$145,000

TABLE CCLXV. ESTIMATED COSTS OF TRANSMISSION SYSTEM, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING
(Basis of 1912)

Item	2,400-Volt D. C.	11,000-Volt A. C.
Copper wire	$246,000	$377,000
Insulators	37,400	52,000
Erection of wire and insulators	60,000	84,000
Ground cables, material and erection	158,660	158,660
Structural steel and concrete in addition to that provided for contact system	30,000	22,000
Towers and foundations where bridges cross over tracks	11,400	15,000
Towers and foundations at river crossings	145,000	145,000
Totals	$688,460	$853,660

of the Chicago railroad terminals is based on the cost of labor and materials as determined for 1912, extended in a manner normal to these estimates (chapter 212), the factors of extension in this case being as follows:

	PER CENT
1. To cover growth in traffic and mileage of railroads, December 31, 1912, to December 31, 1922	30.0
2. Contingencies	20.0
3. Engineering, design, supervision and administration	10.0
4. Interest, insurance and taxes during construction, at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

The values thus derived may be accepted as the total cost on the basis of the requirements of 1922. This cost has been divided among the several railroads to be served, on the basis of energy requirements for the maximum hour.

The estimated total cost by railroads of the transmission system, including additional steel and concrete for supports, river and bridge crossings, and transmission and ground wires, is set forth for both the 2,400-volt direct current and the 11,000-volt alternating current systems, by table CCLXVI.

TABLE CCLXVI. ESTIMATED TOTAL COST OF TRANSMISSION SYSTEM, BY ROADS
(Dec. 31, 1922)

Railroad	2,400-Volt D. C.	11,000-Volt A. C.
Atchison, Topeka & Santa Fe Ry.	$ 15,796	$ 19,586
Baltimore & Ohio R. R.	19,190	23,795
Baltimore & Ohio Chicago Terminal R. R.	21,673	30,593
Calumet, Hammond & Southeastern R. R.	1,828	2,266
Chesapeake & Ohio Ry. of Indiana	4,177	5,180
Chicago & Alton R. R.	18,929	23,471
Chicago & Calumet River R. R.	1,697	2,104
Chicago & Eastern Illinois R. R.	22,581	28,003
Chicago & Erie R. R.	10,574	13,111
Chicago & North Western Ry.	280,148	347,372
Chicago & Western Indiana R. R. and the Belt Railway of Chicago	82,635	102,463
Chicago, Burlington & Quincy R. R.	77,282	95,827
Chicago Great Western R. R.	10,574	13,111
Chicago, Indiana & Southern R. R.	7,963	9,874
Chicago, Indianapolis & Louisville Ry.	12,532	15,539
Chicago Junction Ry.	32.767	40,629
Chicago, Milwaukee & St. Paul Ry.	96,994	120,269
Chicago River & Indiana R. R.*	......	......
Chicago, Rock Island & Pacific Ry.	72,061	89,352
Chicago Short Line Ry.	1,567	1,942
Chicago Union Transfer Ry.†	......	......
Chicago, West Pullman & Southern R. R.	5,091	6,313
Elgin, Joliet & Eastern Ry.	30.156	37,392
Grand Trunk Western Ry.	16.840	20,881
Illinois Central R. R.	143,729	178,218
Illinois Northern Ry.	3,394	4,209
Indiana Harbor Belt R. R.	10,705	13,273
Lake Shore & Michigan Southern Ry.	86,290	106,996
Michigan Central R. R.	28,459	35,288
Minneapolis, St. Paul & Sault Ste. Marie Ry.	7,180	8,903
New York, Chicago & St. Louis R. R.	16,057	19,910
Pere Marquette R. R.	12,924	16,025
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	40,077	49,694
Pittsburgh, Fort Wayne & Chicago Ry.	77,282	95,827
Pullman Railroad	3,003	3,723
Wabash Railroad	30,286	37,554
Totals	$1,305,444	$1,618,693

* Included in the estimates for the Chicago Junction Railway.
† Included in the estimates for the Chicago & Western Indiana Railroad.

The fact should be emphasized that the costs of the transmission system, as exhibited by roads in table CCLXVI, merely represent the share of the several roads in the cost of a transmission system designed for the joint operation of all roads. If, in the actual development of electrification, the individual railroads should prefer to provide individual transmission systems, the costs would be in excess of those set forth. The increase in the case of some of the railroads would be large.

SUBSTATIONS

213.014 General Considerations: Substations constitute necessary facilities incident to the electrification of the Chicago railroad terminals and the cost of these is included in the estimates covering the 2,400-volt direct current system and the 11,000-volt alternating current system. The substations for the 2,400-volt direct current system are designed to receive three-phase alternating current at 33,000 volts and to convert it into 2,400-volt direct current for the contact system; those for the 11,000-volt alternating current system are designed to receive single-phase current at 33,000 volts and to transform it to 11,000 volts for the contact system.

The general considerations governing the locations selected for substations are as follows:

1. Substations are to be placed where distribution of power may be made in several directions.
2. Substations are to be located near large yard loads where possible.
3. Substations are to be located where they may be reached by two separate transmission routes.

Under the plan of the Committee, the 2,400-volt direct current substations are to be so located as to secure economical distribution of current to the load and low potential drop in the return circuit. With the locations selected, the drop in voltage in the positive distributing circuits under maximum starting conditions will not exceed 600 volts. The 11,000-volt alternating current substations are to be so located as to provide suitable feeding points for the contact system in order to prevent inductive interferences in adjacent telephone and telegraph lines. This requires that the distance between substations shall not be more than from 5 to 8 miles and that there shall be a substation at every important stub-end.

213.015 Number, Characteristics and Location of Substations: The estimates for the 2,400-volt direct current system provide for eleven substations varying in capacity from 3,000 to 32,000 kilowatts. Each substation is to consist of a suitable brick building located on railroad property and equipped with a hand-operated crane for handling the heavy apparatus. The apparatus will consist of lightning arresters and oil switches on the incoming three-phase circuits, transformers, switchboards with the necessary instruments, and rotary converters. Six of the substations are to be equipped with suitable switching apparatus so that they will act as tie stations for the transmission lines. This will permit isolation and selection of circuits for desirable or necessary combinations. The transformers are to be of the air blast type. Estimates provide for the use of 1,200-volt rotary converters mounted two in series on a single bed plate, each pair in series being designated as a unit.

The estimates for the 11,000-volt single-phase system provide for 31 substations varying in capacity from 3,000 to 15,000 kilovolt-amperes. The substation buildings are to be of brick and are to be located along the rights-of-way of railroads. Each building is to have a hand-operated crane or hoist. The apparatus is to include incoming and outgoing feeders with lightning arresters and oil switches, step-down transformers of the oil insulated water cooled type and the necessary switchboards and instruments. Attendants will not be required at these substations and therefore the switches will be arranged for remote control from an adjacent signal tower, passenger station or other building where some employe will normally be on duty. The cost of cables and remote control apparatus has been included on the assumption that the distance between substation and control point will not average more than 1,000 feet. Of the substations 16 are to be arranged to act as tie stations for the transmission lines.

For either system of traction the substation equipment to be provided, including transformers and rotary converters, may be operated for five minutes at a load 200 per cent in excess of the rated capacity. A spare unit is to be provided at each substation, thus permitting the maximum load to be carried with one unit out of service.

With either system of traction a substation is to be located in the power station, a plan which will provide an economical arrangement both as to first cost and operating expense. The general assumption concerning land (section 212.10) covers the requirements for substations. The estimates do not include a charge for real estate.

The locations of the substations and the routes of their connecting transmission lines are shown for the 2,400-volt direct current system and for the 11,000-volt alternating current system by figs. 628 and 629, respectively.

The loads, capacities and other characteristics of the substations to be provided are set forth for the 2,400-volt direct current system and for the 11,000-volt alternating current system by tables CCLXVII and CCLXVIII, respectively.

FIG. 628. LOCATIONS OF SUBSTATIONS AND TRANSMISSION LINES, 2,400-VOLT D. C. SYSTEM

FIG. 629. LOCATIONS OF SUBSTATIONS AND TRANSMISSION LINES, 11,000-VOLT A. C. SYSTEM

TABLE CCLXVII. CHARACTERISTICS OF SUBSTATIONS FOR 2,400-VOLT D. C. SYSTEM

Sub-station No.	Input to Substations for Average Day Kilowatt-Hours			Load Factor Per Cent	Units		Total Rated Capacity Kilowatts
	Average Hour	Maximum Hour	Total		No.	Capacity Kilowatts	
1	2	3	4	5	0	7	8
1	1,273	2,444	30,555	52.1	3	1,000	3,000
2	1,860	5,309	44,774	35.2	4	2,000	8,000
3	7,308	10,019	175,391	73.0	4	4,000	16,000
4	20,207	30,007	484,985	07.4	8	4,000	32,000
*5	16,782	26,348	402,774	63.7	7	4,000	28,000
6	5,914	7,493	141,941	78.8	3	4,000	12,000
7	10,700	15,515	256,785	69.0	5	4,000	20,000
8	6,410	11,391	153,838	55.3	4	4,000	16,000
9	3,684	6,171	88,418	59.7	4	2,000	8,000
10	866	2,177	20,783	39.8	3	1,000	3,000
11	497	2,485	11,920	20.0	4	1,000	4,000
Totals	75,507	119,359	1,812,170	....	49	....	150,000

* Substation in power station.

TABLE CCLXVIII. CHARACTERISTICS OF SUBSTATIONS FOR 11,000-VOLT A. C. SYSTEM

Sub-station No.	Input to Substations for Average Day Kilowatt-Hours			Load Factor Per Cent	Units		Total Rated Capacity Kilovolt-Amperes
	Average Hour	Maximum Hour	Total		No.	Capacity Kilovolt-Amperes	
1	2	3	4	5	0	7	8
1	238	458	5,718	52	2	1,500	3,000
2	483	930	11,580	52	2	1,500	3,000
3	599	1,300	14,387	44	2	1,500	3,000
4	1,029	2,940	24,696	35	2	3,000	0,000
5	281	700	6,749	40	2	1,500	3,000
6	399	1,000	9,564	40	2	1,500	3,000
7	1,680	2,560	40,316	65	2	2,500	5,000
8	419	700	10,002	60	2	1,500	3,000
9	3,268	4,875	78,423	67	2	5,000	10,000
10	3,228	4,310	77,477	75	2	4,000	8,000
11	691	1,060	10,589	65	2	2,000	4,000
12	8,615	11,300	206,754	76	3	5,000	15,000
13	2,897	3,860	69,532	75	2	4.000	8,000
14	7,821	11,150	187,708	70	3	5,000	15,000
15	244	950	5,855	26	2	1,500	3,000
*16	6,543	9,350	157.050	70	3	4,500	13,500
17	2,799	5,100	67,174	55	2	5,000	10,000
18	2,484	3,100	59,622	78	2	3,000	6,000
19	98	217	2,362	45	2	1.500	3,000
20	244	1,220	5.856	20	2	1,500	3,000
21	5,153	7,500	123,073	68	3	4,000	12,000
22	2,989	4,600	71,729	65	2	5,000	10,000
23	3,510	5,350	84,248	65	2	5,000	10,000
24	6,617	9,500	158,819	70	3	5,000	15,000
25	574	1,140	13,777	50	2	1,500	3,000
26	3,160	6,320	75,842	50	2	6,000	12,000
27	1,741	3,480	41,774	50	2	3,000	6,000
28	1,329	2,220	31,885	60	2	1,500	3,000
29	197	350	4,719	56	2	1,500	3,000
30	468	1,040	11,229	45	2	1,500	3,000
31	184	510	4,413	37	2	1,500	3,000
Totals	69,981	109,150	1,679,582	..	67	....	207,500

* Substation in power station.

213.016 Estimates of Costs of Substations on the Basis of the Requirements of 1912, Excluding all Allowances for Contingencies and for Engineering: The costs of the substations already described have been estimated on the basis of quoted costs of equipment and known costs of buildings for similar purposes, and checked by comparison with the unit costs of a number of completed substations of various types and capacities. The estimates of costs, excluding all allowances for contingencies and for engineering, for the substations required for the 2,400-volt direct current system and for the 11,000-volt alternating current system, are set forth by tables CCLXIX and CCLXX, respectively.

TABLE CCLXIX. ESTIMATED COSTS OF SUBSTATIONS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING, 2,400-VOLT D. C. SYSTEM

(Basis of 1912)

Substation No.	Total Capacity of Initial Installation, Kilowatts	Cost
1	3,000	$130,990
2	8,000	222,920
3	16,000	318,840
4	32,000	603,960
*5	28,000	478,590
6	12,000	256,560
7	20,000	401,750
8	16,000	325,440
9	8,000	217,250
10	3,000	130,990
11	4,000	169,220
Totals	150,000	$3,256,510

* Substation in power station.

TABLE CCLXX. ESTIMATED COSTS OF SUBSTATIONS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING, 11,000-VOLT A. C. SYSTEM

(Basis of 1912)

Substation No.	Total Capacity of Initial Installation, Kilovolt-Amperes	Cost
1	3,000	$24,910
2	3,000	26,700
3	3,000	26,700
4	6,000	36,190
5	3,000	24,910
6	3,000	24,910
7	5,000	38,160
8	3,000	26,700
9	10,000	45,510
10	8,000	43,940
11	4,000	31,430
12	15,000	66,090
13	8,000	41,980
14	15,000	71,080
15	3,000	29,580
*16	13,500	41,590
17	10,000	45.510
18	6,000	34.400
19	3,000	24,880
20	3,000	28,480
21	12,000	73,880
22	10,000	37,090
23	10,000	36,400
24	15,000	59,010
25	3,000	30,270
26	12,000	43,340
27	6.000	38,120
28	3,000	33,840
29	3.000	25,870
30	3.000	26,700
31	3,000	26,700
Totals..........	207.500	$1,164,870

* Substation in power station.

213.017 Estimated Total Cost of Substations: The estimated total cost of the substations for the electric operation of the Chicago railroad terminals is based upon the cost of labor and materials as determined for 1912, extended in a manner normal to these estimates (chapter 212), the factors of extension in this case being as follows:

	PER CENT
1. To cover growth in traffic and mileage of railroads, December 31, 1912, to December 31, 1922 . . .	30.0
2. Contingencies	10.0
3. Engineering, design, supervision and administration	10 0
4. Interest, insurance and taxes during construction, at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

The values thus derived may be accepted as the total cost of substations on the basis of the requirements of 1922. These costs have been apportioned to the several railroads to be served, on the basis of the energy requirements for the maximum hour.

The estimated total cost by railroads of the substations, including buildings and equipment, for both the 2,400-volt direct current and the 11,000-volt alternating current systems, is set forth by table CCLXXI.

TABLE CCLXXI. ESTIMATED TOTAL COST OF SUBSTATIONS, INCLUDING BUILDINGS AND EQUIPMENT, BY ROADS

(Dec. 31, 1922)

Railroad	2,400-Volt D. C.	11,000-Volt A. C.
Atchison, Topeka & Santa Fe Ry.	$ 68,490	$ 24,499
Baltimore & Ohio R. R.	83,207	29,764
Baltimore & Ohio Chicago Terminal R. R.	106,981	38,268
Calumet, Hammond & Southeastern R. R.	7,924	2,835
Chesapeake & Ohio Ry. of Indiana	18,113	6,480
Chicago & Alton R. R.	82,075	29,359
Chicago & Calumet River R. R.	7,358	2,632
Chicago & Eastern Illinois R. R.	97,924	35,028
Chicago & Erie R. R.	45,849	16,400
Chicago & North Western Ry.	1,214,713	434,509
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	358,300	128,166
Chicago, Burlington & Quincy R. R.	335,093	119,864
Chicago Great Western R. R	45,849	16,400
Chicago, Indiana & Southern R. R.	34,528	12,351
Chicago, Indianapolis & Louisville Ry.	54,339	19,437
Chicago Junction Ry.	142,075	50,821
Chicago, Milwaukee & St. Paul Ry.	420,564	150,438
Chicago River & Indiana R. R.*	...	...
Chicago, Rock Island & Pacific Ry	312,451	111,765
Chicago Short Line Ry.	6,792	2,430
Chicago Union Transfer Ry.†	...	...
Chicago, West Pullman & Southern R. R.	22,075	7,896
Elgin, Joliet & Eastern Ry.	130,754	46,771
Grand Trunk Western Ry.	73,019	26,119
Illinois Central R. R.	623,206	222,924
Illinois Northern Ry.	14,717	5,264
Indiana Harbor Belt R. R.	46,415	16,603
Lake Shore & Michigan Southern Ry.	374,149	133,835
Michigan Central R. R.	123,396	44,139
Minneapolis, St. Paul & Sault Ste. Marie Ry.	31,132	11,136
New York, Chicago & St. Louis R. R.	69,622	24,904
Pere Marquette R. R.	56,037	20,045
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	173,773	62,159
Pittsburgh, Ft. Wayne & Chicago Ry.	335,093	119,864
Pullman R. R.	13,019	4,657
Wabash R. R.	131,320	46,974
Totals	$5,660,352	$2,024,736

* Included in the estimates for the Chicago Junction Railway.

† Included in the estimates for the Chicago & Western Indiana Railroad.

The fact should be emphasized that the substation costs as exhibited by roads in table CCLXXI merely represent the share of the several roads in the cost of the group of substations designed for the joint operation of all roads. If, in the actual development of electrification, individual roads should prefer to provide individual substations, their costs would be in excess of those set forth. The increase, especially for the smaller roads, would be material.

SWITCHING STATIONS

213.018 General Considerations: With both the 2,400-volt direct current system and the 11,000-volt alternating current system, it is necessary to provide switching stations at various points throughout the terminals for the sectionalization of the overhead conductors of the contact system. Such switching stations will consist of suitable apparatus to allow conductors to be isolated in the event of disorder due to overload, short circuits or other causes.

213.019 Locations and Characteristics of the Switching Stations: Switching stations for main track contact conductors in the terminal are to be provided as follows:

1. At intervals of from two to three miles, usually at interlocking plants or passenger stations where there are crossovers.
2. At all important junction points.
3. At all track crossings at grade.

A substation has been considered as serving the purpose of a switching station and as taking the place of one that would otherwise be required.

The estimates of cost of switching stations for the 2,400-volt direct current system have been based upon the assumed use of carbon break circuit breakers mounted on suitable panels. This type of switch requires protection from the weather, and for this purpose a small and inexpensive building is to be provided at each location selected for a switching station. The estimates for the 11,000-volt alternating current system have been based upon the assumed use of outdoor type oil switches mounted on the overhead anchor bridges of the contact system. The switches for both systems are to be controlled from neighboring signal towers or passenger stations located at an assumed average distance of 1,000 feet from the switching stations. The cost of this remote control apparatus is included in the cost of the switching stations.

For the sectionalization of yards and unimportant junction connections, outdoor type non-automatic switches, such as knife switches for the 2,400-volt direct current system and hand operated oil switches for the 11,000-volt alternating current system, are to be provided.

213.020 Estimated Costs of Switching Stations on the Basis of the Requirements of 1912, Excluding all Allowances for Contingencies and for

Engineering: The costs of the switching stations already described have been estimated on the basis of quoted costs of equipment and known costs of buildings used for the same purpose. The estimates of cost, excluding all allowances for contingencies and for engineering, of the switching stations required for the 2,400-volt direct current system and for the 11,000-volt alternating current system are set forth by tables CCLXXII and CCLXXIII, respectively.

TABLE CCLXXII. ESTIMATED COSTS OF SWITCHING STATIONS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING, 2,400-VOLT D. C. SYSTEM

(Basis of 1912)

Number of Switching Stations	Number of Feeders per Station	Cost per Station	Total Cost
1	2	3	4
2	2	$ 2,050	$ 4,100
1	3	2,700	2,700
29	4	3,350	97,150
4	5	4,150	16,600
15	6	4,800	72,000
1	7	5,350	5,350
17	8	6,250	106,250
3	9	6,900	20,700
10	10	7,550	75,500
10	12	9,000	90,000
1	13	9,650	9,650
6	14	10,300	61,800
1	15	11,100	11,100
11	16	11,750	129,250
4	18	13,050	52,200
3	20	14,500	43,500
1	22	15,800	15,800
1	24	17,250	17,250
1	30	21,150	21,150
1	34	23,750	23,750
122			$875,800

TABLE CCLXXIII. ESTIMATED COSTS OF SWITCHING STATIONS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING, 11,000-VOLT A. C. SYSTEM

(Basis of 1912)

Number of Switching Stations	Number of Feeders per Station	Cost per Station	Total Cost
1	2	3	4
2	2	$ 700	$ 1,400
27	4	1,400	37,800
4	5	1,750	7,000
14	6	2,100	29,400
1	7	2,450	2,450
16	8	2,800	44,800
3	9	3,150	9,450
9	10	3,500	31,500
6	12	4,200	25,200
1	13	4,550	4,550
5	14	4,900	24,500
1	15	5,250	5,250
9	16	5,600	50,400
3	18	6,300	18,900
3	20	7,000	21,000
1	22	7,700	7,700
1	24	8,400	8,400
106			$329,700

213.021 Estimated Total Cost of Switching Stations: The estimated total cost of switching stations for the electric operation of the Chicago railroad terminals is based on the cost of labor and materials as determined for 1912, extended in a manner normal to these estimates (chapter 212), the factors of extension in this case being as follows:

		PER CENT
1.	To cover growth in traffic and mileage of railroads, December 31, 1916, to December 31, 1922	30.0
2.	Contingencies	10.0
3.	Engineering, design, supervision and administration	10.0
4.	Interest, insurance and taxes during construction, at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

The values thus derived may be accepted as the total cost on the basis of the requirements of 1922. These costs have been apportioned to the several railroads to be served, on the basis of the electrified track mileage.

The estimated total cost by railroads of the switching stations, including buildings and equipment installed and connected, for both the 2,400-volt direct current system and the 11,000-volt alternating current system, is set forth by table CCLXXIV.

TABLE CCLXXIV. ESTIMATED TOTAL COST OF SWITCHING STATIONS, INCLUDING BUILDINGS AND EQUIPMENT, BY ROADS

(Dec. 31, 1922)

Railroad	2,400-Volt D. C.	11,000-Volt A. C.
Atchison, Topeka & Santa Fe Ry.	$ 39,579	$14,900
Baltimore & Ohio R. R.	26,183	9,857
Baltimore & Ohio Chicago Terminal R. R.	50,540	19,026
Calumet, Hammond & Southeastern R. R.	2,588	974
Chesapeake & Ohio Ry. of Indiana	76	29
Chicago & Alton R. R.	26,107	9,828
Chicago & Calumet River R. R.	9,286	3,496
Chicago & Eastern Illinois R. R.	10,047	3,782
Chicago & Erie R. R.	15,223	5,731
Chicago & North Western Ry.	235,954	88,827
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	141,573	53,296
Chicago, Burlington & Quincy R. R.	81,442	30,659
Chicago Great Western R. R.	9,134	3,438
Chicago, Indiana & Southern R. R.	5,176	1,948
Chicago, Indianapolis & Louisville Ry.	2,436	917
Chicago Junction Ry.	88,293	33,238
Chicago, Milwaukee & St. Paul Ry.	115,085	43,324
Chicago River & Indiana R. R.	4,567	1,719
Chicago, Rock Island & Pacific Ry.	60,891	22,923
Chicago Short Line Ry.	2,283	860
Chicago Union Transfer Ry.	3,653	1,375
Chicago, West Pullman & Southern R. R.	7,916	2,980
Elgin, Joliet & Eastern Ry.	50,235	18,911
Grand Trunk Western Ry.	28,467	10,716
Illinois Central R. R.	149,184	56,161
Illinois Northern Ry.	9,286	3,496
Indiana Harbor Belt R. R.	10,352	3,897
Lake Shore & Michigan Southern Ry.	72,309	27,221
Michigan Central R. R.	30,141	11,347
Minneapolis, St. Paul & Sault Ste. Marie Ry.*	.....	......
New York, Chicago & St. Louis R. R.	25,727	9,685
Pere Marquette R. R.	4,262	1,605
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	60,282	22,694
Pittsburgh, Fort Wayne & Chicago Ry.	92,250	34,728
Pullman R. R.	20,094	7,565
Wabash R. R.	31,664	11,920
Totals	$1,522,285	$573,073

* Owns no track to be electrified.

The fact should be emphasized that the switching station costs, as exhibited by roads in table CCLXXIV, merely represent the share of the several roads in the cost of the group of switching stations designed for joint operation of all roads. If, in the actual development of electrification, individual roads should prefer to provide individual substation and switching station systems, the costs of the switching stations required for these individual roads would differ materially from those set forth.

OVERHEAD CONTACT SYSTEM*

213.022 Definition: The overhead type of contact system for the delivery of electric current to locomotives and cars has been made the basis of estimates of the cost of equipping the railroad lines of the Chicago terminals for electric operation. This type of contact system consists of one or more conductor wires of suitable size and material, suspended in desired position above the track from a catenary messenger wire, and of steel structures, or poles of wood or steel, set at intervals along the line to support and maintain the position of the wires. As a basis for the estimates of cost, a system suitable for single-phase alternating current at 11,000 volts and for direct current at 2,400 volts has been designed. The types of construction chosen are the result of a careful study of the systems employed on existing electrified steam railroads using high voltage overhead contact. Owing to local or special conditions disclosed by the investigations of the Committee, the types of construction selected do not conform to present types in detail, but embody as far as possible those features which have been shown by experience to be satisfactory and which avoid objectionable and unnecessary details and devices.

213.023 Factors of Design: The design of the overhead contact system has involved the recognition of certain factors, which are discussed in the paragraphs which follow.

Clearances

In the designs prepared as a basis for the estimates, a clearance of 25 feet has been provided between the top of the rail and the conductor wire at its point of support under the supporting structure, except in cases where permanent overhead obstructions will not permit such clearance. In fixing this distance it has been the intention to provide for a minimum clearance of 24 feet, 2 inches, between the top of the rail and the conductor wire under the conditions of maximum sag. This minimum clearance permits the safe operation of trains under conditions which require trainmen to give signals by swinging a lantern at arm's length while standing on the running board of a box car. It is assumed that the running board of a car of maximum allowable height will be 15 feet, 0.5 inch, above the top of the rail and that the reach of a trainman with a lantern will be 8 feet, 8 inches, allowing a minimum clearance of 5.5 inches between the lantern and the contact wire. In cases where permanent overhead obstructions will not permit the standard clearance, bridge warnings are to be provided. These are described and their estimated cost is given in sections 213.033 to 213.036. The minimum height of the wire above the track in such cases has been fixed at 15 feet, 10 inches, which provides a clearance of 9.5 inches between the wire and the running board of a car 15 feet, 0.5 inch, high. A minimum distance of 8.0 inches is allowed between the wire and the supporting structure, making the minimum allowable clearance for permanent overhead obstructions 16 feet, 6 inches. Structures under which the clearance is less than 16 feet, 6 inches, are to be raised or changed to provide the required height. The costs incident to such changes are not included in the estimates for the overhead contact system but are presented separately in section 213.075. Where the contact wire is required to pass under foot and street bridges, suitable screen guards are to be provided to prevent persons from touching or interfering with the wires. The clearance distances given are those adopted as recommended practice by the American Railway Association.

The location of existing wires paralleling or crossing the right-of-way has not influenced the designs of the overhead contact system, as it has been assumed that all interferences of this kind will be removed, as described in sections 213.076 to 213.080, where the estimated cost of the necessary changes is also given. The characteristics of materials required for the overhead contact system are given in table CCLXXV. The summary following the table shows unit stresses and maximum load conditions.

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* A complete file of all details of costs, quantities, designs and calculations preserved in the Archives of the Committee, Vols. E 64 to E 86.

TABLE CCLXXV. CHARACTERISTICS OF MATERIALS

Material	Modulus of Elasticity	Ultimate Strength Lb. per Sq. In.	Safe Load Lb. per Sq. In.	Elastic Limit Per Cent of Ultimate Strength	Coefficient of Expansion per Degree Fahrenheit
1	2	3	4	5	6
Iron wire	29,000,000	57,000	26,000	65	0.0000066
Steel wire	25,000,000	190,000	36,000	60	0.0000066
Copper wire	16,000,000	50,000	25,000	60	0.0000097

UNIT STRESSES

Structural Steel:

Tension . . . . . 25,000 lb. per sq. in.

Compression . . . 25,000—100 $\frac{l}{r}$ lb. per sq. in. where
l = length of member in inches
r = radius of gyration.
$\frac{l}{r}$ shall not exceed 180.

Shear . . . . . 12,000 lb. per sq. in. on shop rivets and pins.
10,000 lb. per sq. in. on field rivets and bolts.

Bearing . . . . . 20,000 lb. per sq. in. on shop rivets and pins.

Concrete Foundations:

Bearing . . . . . . 400 lb. per sq. in.

Soil Foundations:

Bearing, Maximum 3,000 lb. per sq. ft.

MAXIMUM LOAD CONDITIONS

Sleet Loads:

Coating of ice 0.5 inch thick, making an increase of 1.0 inch in the diameter of all wires, cables and hangers.

Wind Loads:

On projected area of ice-coated wires, cables and hangers, 8.0 lb. per sq. ft.

On projected area of bare wires, cables and hangers, 15 lb. per sq. ft.

On structural steel, 30 lb. per sq. ft.

Temperatures:

From 20 degrees below zero to 120 degrees Fahrenheit.

Classification of Tracks

Owing to differences in physical and operating conditions between different classes of railroad track, it has been necessary to prepare separate standard designs for the overhead contact system for each class of track. Standard designs have therefore been prepared to meet the conditions found on the following classes of track:

1. Main tracks, including all running, passing and crossover tracks regularly used for passenger and freight traffic.
2. Yard tracks, including all trackage in yards other than main tracks.
3. Industrial tracks, including all tracks serving industries, such as:
    a. Spur tracks which connect with the main or yard tracks in such manner that the contact system for them cannot be made a part of that provided for other tracks.
    b. Industrial tracks which are grouped in small yards and are so located that the contact system for them may be included under joint construction.

There are some tracks so located that it has not been practicable to design any type of contact system which would meet the requirements of electric operation. For example, tracks in buildings or under cranes cannot be equipped with an overhead contact system. The amount of such trackage, which is mostly industrial, is small (chapter 208).

213.024 Overhead Construction for the 11,000-Volt Alternating Current System: Different general types of overhead contact construction for the 11,000-volt alternating current system have been designed for use in connection with main tracks, yard tracks and industrial tracks. Descriptions of each type are given in the following paragraphs.

Main Track Construction

The type of construction for main tracks which has served as the basis for estimates of cost consists of a $\frac{5}{8}$-inch stranded steel messenger cable of extra high strength, supported above the track by means of insulators attached to the bottom of the cross-spans of structural steel bridges or to cross catenary spans, spaced normally at intervals of 300 feet. From this primary messenger, a secondary messenger of No. 0000 A. W. G. solid steel wire is suspended by means of hangers of varying lengths spaced at intervals of 10 feet. A No. 0000 A. W. G. grooved solid copper contact wire is suspended about two inches below the secondary messenger, which supports it by means of clips placed midway between hangers. Under the normal load at 60 degrees Fahrenheit the primary messenger will have a sag of five feet. The hangers are of such lengths that with this sag the contact wire will be practically parallel to the surface of the track and 25 feet above the top of the rails. This construction provides a flexible contact system without sudden changes in grade and without "hard spots." On curves the spacing of supporting structures is to be reduced, and the messenger cable is to be suspended in such a manner that, by the use of special inclined hangers, the contact wire will be held in place approximately above the center line of the track. In cases where the curvature is more than four degrees, inclined hangers are not to be used but an intermediate steel pull-off pole, either guyed or self-supporting, is to be placed between supporting structures and the messenger and contact wires are to be pulled to a position which will permit the contact wire to have its place approximately over the center of the track. Under no condition of curvature will the departure of the contact wire from position above the center line of track exceed 12 inches. Where permanent obstructions will not permit the standard height to be maintained, the contact wire will descend at grades of from one to two per cent, depending upon the probable operating speeds at the point under consideration. In order to accomplish this the messenger wire must also descend. The stresses which this system of wires is required to withstand under various conditions have been carefully determined, and those produced by the maximum wind and ice loading at 0 degrees Fahrenheit, this being considered the most severe combination of loads, are found to be within the safe limits previously specified. Except at anchor bridge structures, which are to be placed at certain points along the line, no allowance has been made for broken wires because, with proper provision in the design, the failure of wire construction is not more probable than that of other types of construction. The insulators to which the wires are to be attached cannot be regarded as possessing the same degree of reliability, and the possibility of a broken insulator at a support, with the consequent unbalanced condition of loading, has been provided for. Such a condition would remove the load of the messenger system from one bridge and allow the wire to sag for a 600-foot span, thereby placing an unbalanced load on the adjacent bridges. Allowance has also been made for the unbalanced conditions caused by a wind and ice load acting on one span and not on the adjacent ones. The design of the structures employed to maintain the position of the messenger and contact wires will be hereinafter described (section 213.025).

Yard Track Construction

A type of overhead construction simpler and lighter than that used for main lines has been selected for yard tracks. It consists of a $\frac{3}{8}$-inch stranded steel messenger cable of extra high strength, from which a No. 00 A. W. G. grooved copper contact wire is suspended by light hangers spaced at intervals of 15 feet. Over busy tracks, such as ladder tracks or open tracks much used for switching, No. 0000 A. W. G. contact wire is used. The contact wire is suspended at the standard clearance distance of 25 feet above the top of the rails and on tangents is directly above the center line of the track. On curves and crossovers, departure from a position directly above the center line is permitted, but such departure will not exceed six inches, pull-off poles or structures being provided when necessary to maintain this position. The messenger is normally supported by cross catenary spans located at 300-foot intervals, but both the character and spacing of supports are frequently modified to fit the many and varying conditions to be found in yards. The design and location of the structures provided to maintain the position of the messenger and contact wires over yard tracks will be hereinafter described (section 213.025).

Industrial Track Construction

Owing to the fact that much of the industrial track is laid in the least expensive manner and is subjected to frequent changes in arrangement, the overhead construction selected for such tracks is of a type which costs considerably less than that used either on main or on yard tracks. The design provides for a $\frac{7}{16}$-inch stranded steel messenger cable, from which a No. 00 A. W. G. copper contact wire is suspended by means of $\frac{1}{4}$-inch hangers spaced at intervals of 15 feet. The messenger cable is supported by bracket or by cross-span construction with wooden poles spaced at intervals of 150 feet on tangent track, and at such distance on curves as is found necessary to maintain the position of the contact wire within six inches of a line directly above the center of the track. Where the number of parallel tracks in industrial yards is greater than five or where industrial yards are similar in other respects to the more important yards, the type of overhead construction and supporting structures designed for yards has been used. The description and location of structures provided to maintain the position of the messenger and contact wires over industrial tracks are treated in the following section.

213.025 Supporting Structures for Overhead Contact System for Alternating Current at 11,000 Volts: Standard designs of structures for supporting the overhead construction described in the preceding section, upon which estimates are based, have been prepared for each class of track. Structures of special design are also provided to meet special conditions. Existing structures which can be adapted or modified to serve as supporting structures for the overhead contact system, are to be retained. The designs employed and the methods followed with reference to spacing, anchoring and other factors will be set forth in the paragraphs which follow.

Use Made of Existing Structures

In practically all cases it has been found that existing signal bridges can be adapted to the requirements of supporting structures for the overhead contact system by raising the cross-spans to the proper elevation. To accomplish this, provision has been made for splicing additional sections to the bridge legs and to the pipe and wire connections employed in the operation of the signals. This process necessitates the raising of the signals now supported by the bridges, but since in most cases this increased height of signals would not be objectionable, no provision has been made to cover cost of alterations or changes in the location of the signals on the bridges. It has been assumed that each existing signal bridge will be used in place of the new supporting structure which would otherwise be required. The cost of altering signal bridges has been included in the cost of the structures for the contact system.

Supporting Structures for Overhead Contact System for Main Tracks

The Committee's specifications provide a 300-foot spacing of supporting structures for the overhead contact system along main line tracks. Designs for the supporting structures have been based upon the loading imposed by the messenger cables and their connected wires, considered in connection with maximum wind and ice loads (section 213.023). Preliminary designs of the following types of structures have been prepared:

1. Strut bridge with straight posts.
2. Strut bridge with spread posts.
3. Cross catenary with guyed structural poles.
4. Cross catenary with guyed tubular poles.

The estimated costs of the several types of supporting structures for spanning various numbers of tracks were plotted as shown by fig. 630.

It will be seen that the cross catenary type of support with guyed tubular poles is considerably cheaper to install than any of the other types. This type also offers less obstruction to the view of signals than any form of structural steel span. The cross catenary type of structure with guyed tubular poles has therefore been adopted for

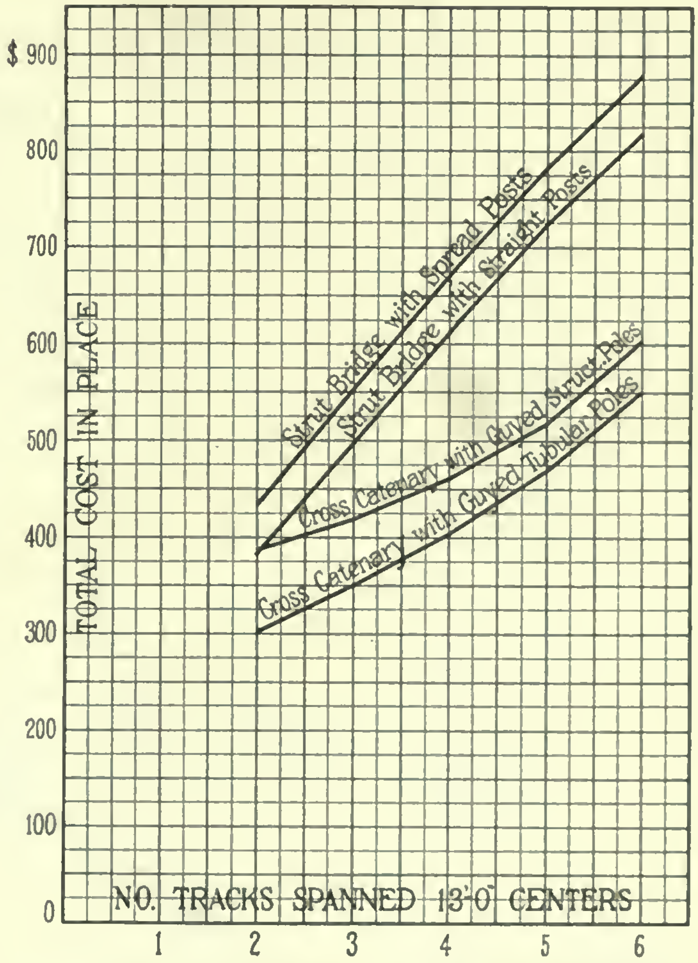

FIG. 630. COST DIAGRAM. Estimated Costs of Different Types of Supporting Structures for Main Track Overhead Contact Construction.

use wherever right-of-way conditions will permit. Designs of this type of construction have been completed and used as a basis for the estimates. They are shown by drawings presented as figs. 631 to 633, inclusive.

In cases where tracks are located close to the edge of the right-of-way or where other local conditions prevent the use of guys, a strut bridge with straight posts will cost less than the unguyed structure with spread posts covered by the preliminary designs. This type has therefore been adopted for such locations, and designs completed and used as a basis for the estimates. These designs are shown by the drawings presented as figs. 634 to 636, inclusive.

Anchor bridges have been provided at intervals of two miles unless special conditions require closer spacing. They are also located at all important dead-ends and on both sides of track crossings at grade, whether of steam or electric railroads. The anchor bridges are designed to withstand the load imposed by a condition of maximum wind and ice strains on the wires with all wires broken on one side of the structure. The designs of anchor bridges for two, four and six tracks which have been used as the basis of estimates are shown by figs. 637 to 639, inclusive.

All of these main track structures are designed to support ten auxiliary wires in addition to the load of the contact and supporting wires. Four transmission wires and one ground wire may be placed on each of the two extensions to the posts or poles at the sides of the cross-span. In cases where more transmission wires are required, additions to the structures are to be provided. The cost of such additions, as well as the cost of all wires, pins and insulators for transmission lines, are presented separately under the estimates of

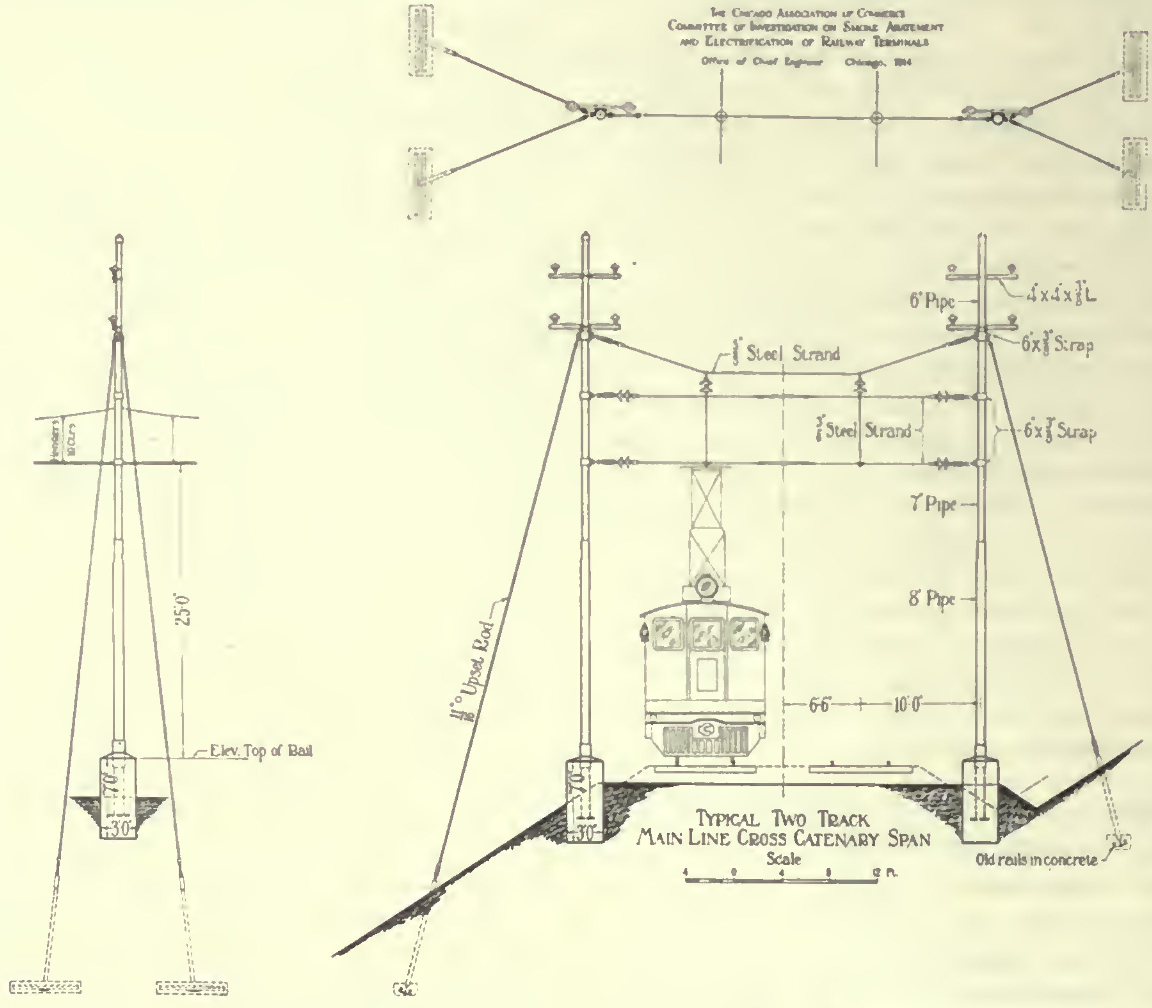

FIG. 631. TYPICAL TWO TRACK CROSS CATENARY SUPPORT FOR CONTACT SYSTEM

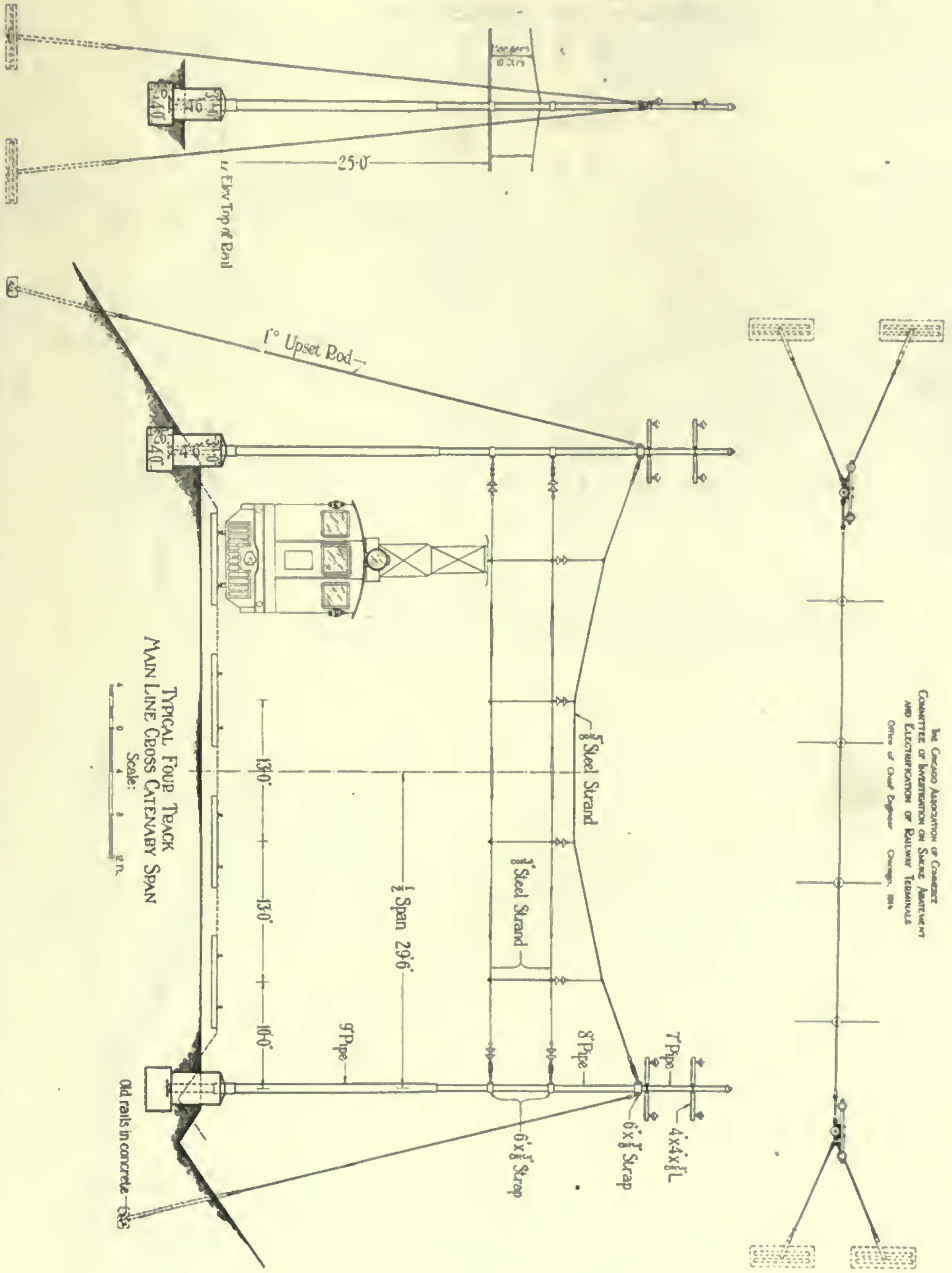

FIG. 632. TYPICAL FOUR TRACK CROSS CATENARY SUPPORT FOR CONTACT SYSTEM

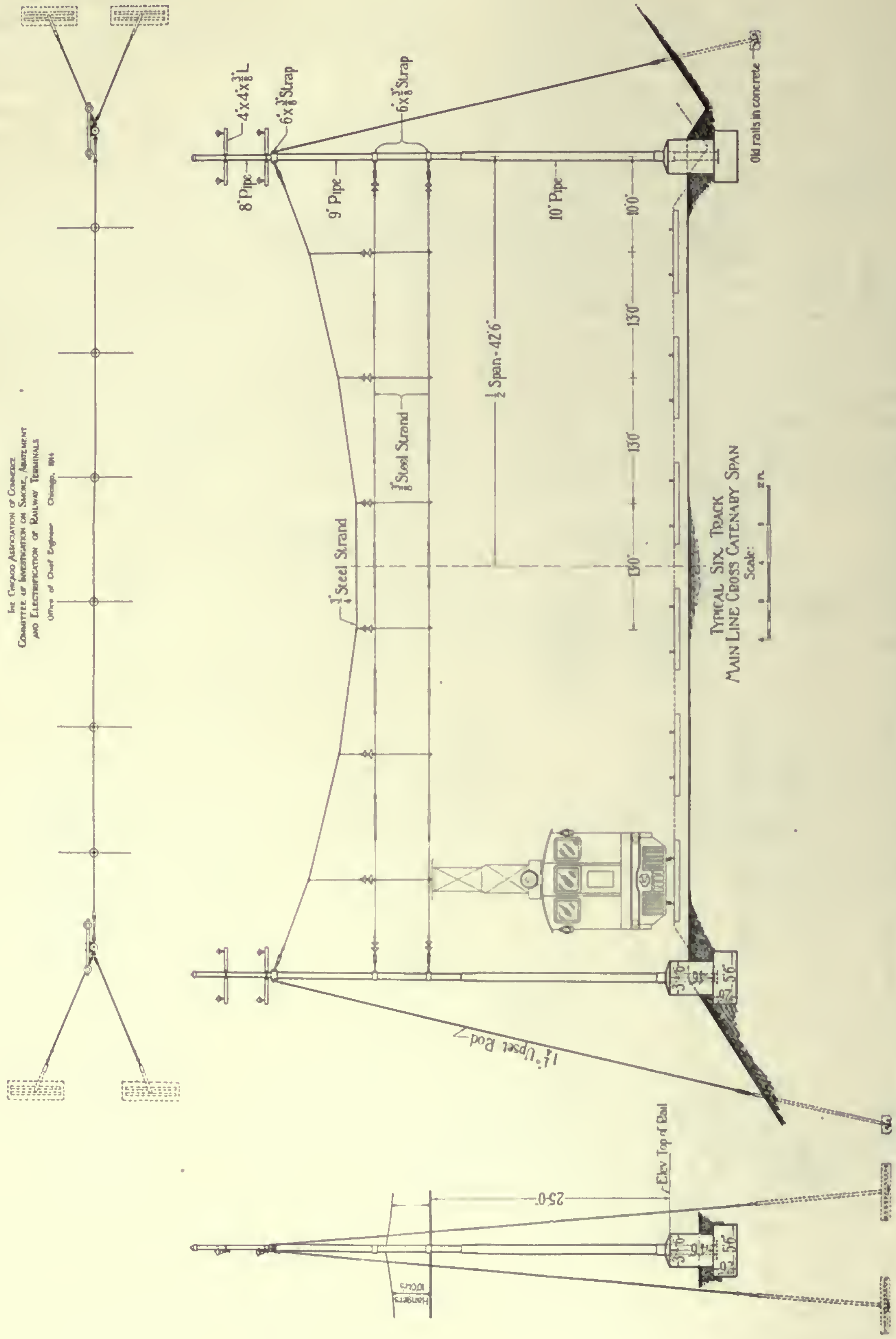

FIG. 633. TYPICAL SIX TRACK CROSS CATENARY SUPPORT FOR CONTACT SYSTEM

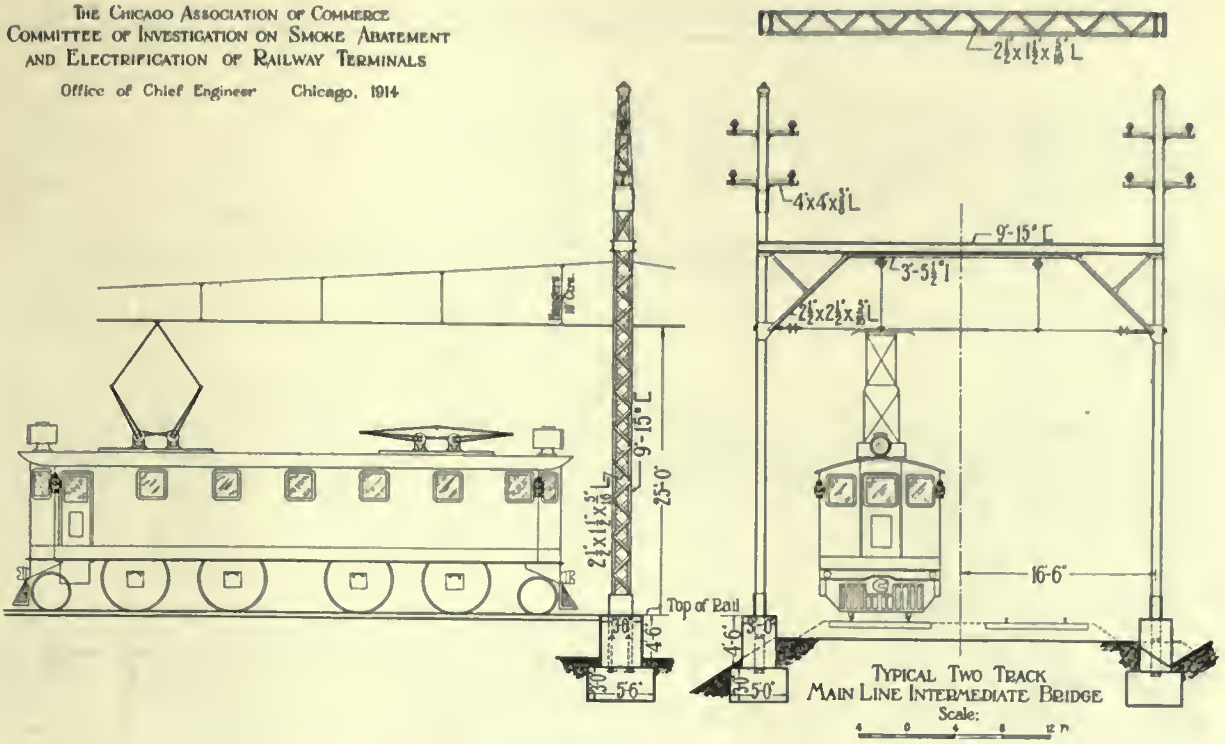

FIG. 634. TYPICAL TWO TRACK STRUT BRIDGE WITH STRAIGHT POSTS

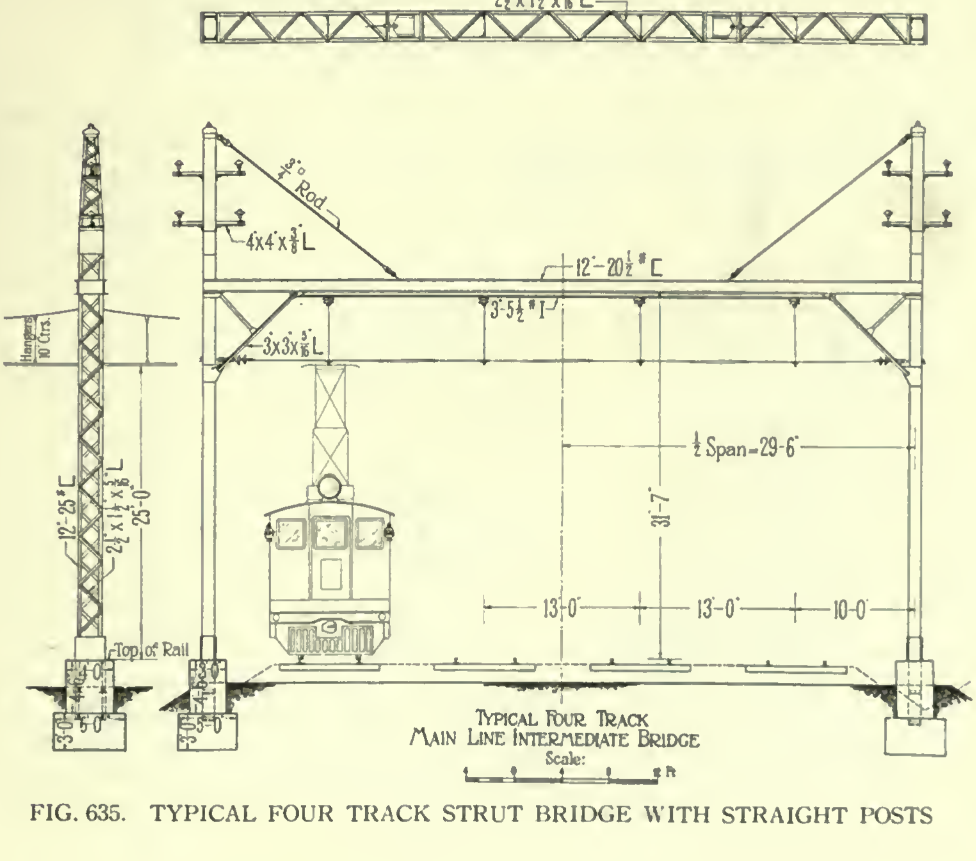

FIG. 635. TYPICAL FOUR TRACK STRUT BRIDGE WITH STRAIGHT POSTS

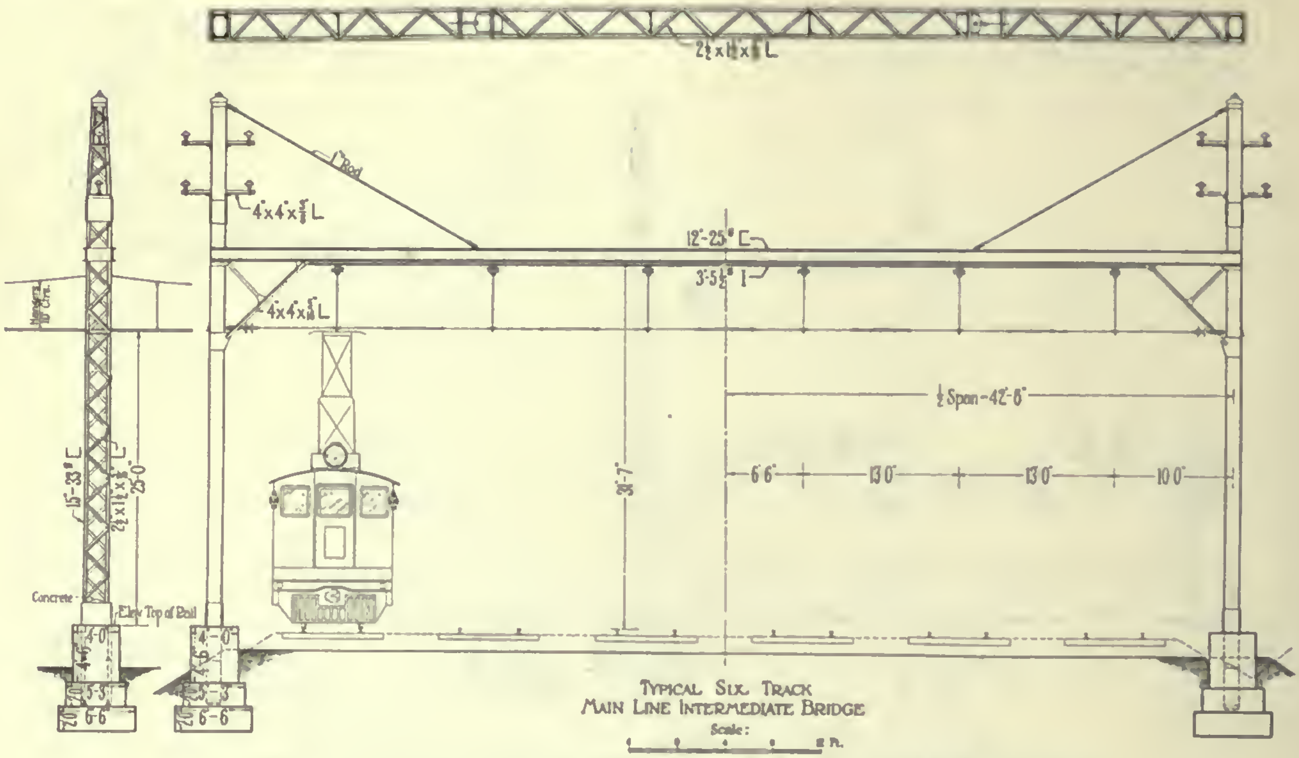

FIG. 636. TYPICAL SIX TRACK STRUT BRIDGE WITH STRAIGHT POSTS

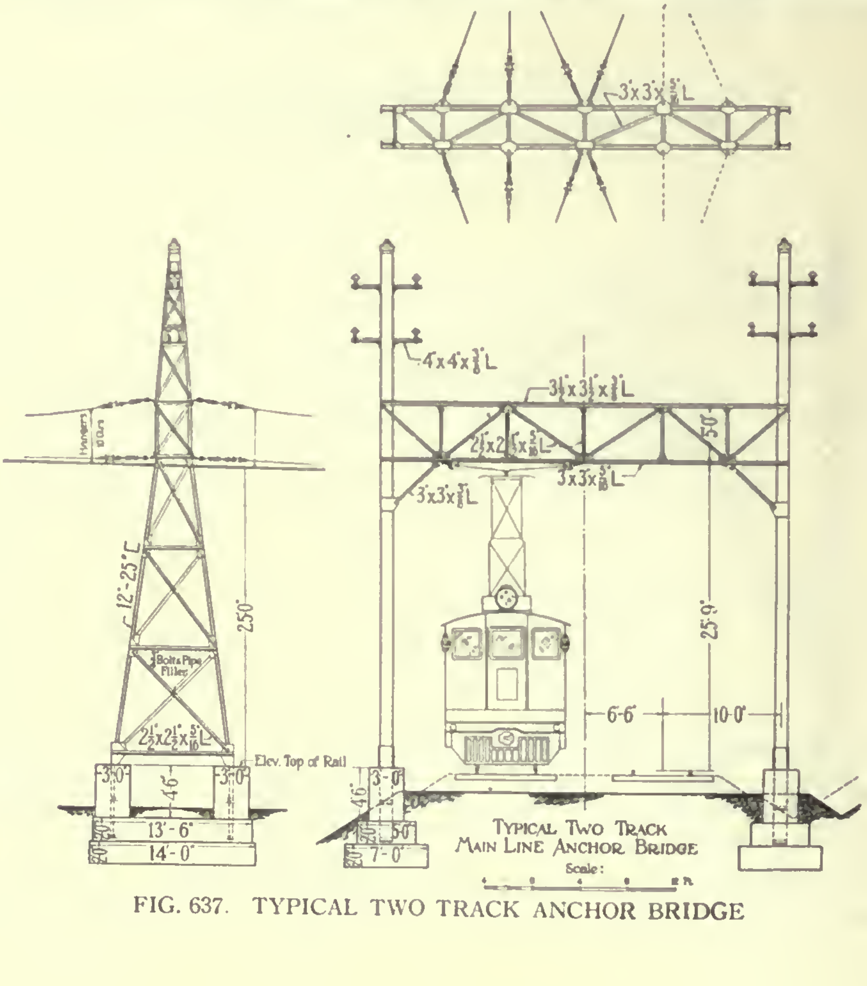

FIG. 637. TYPICAL TWO TRACK ANCHOR BRIDGE

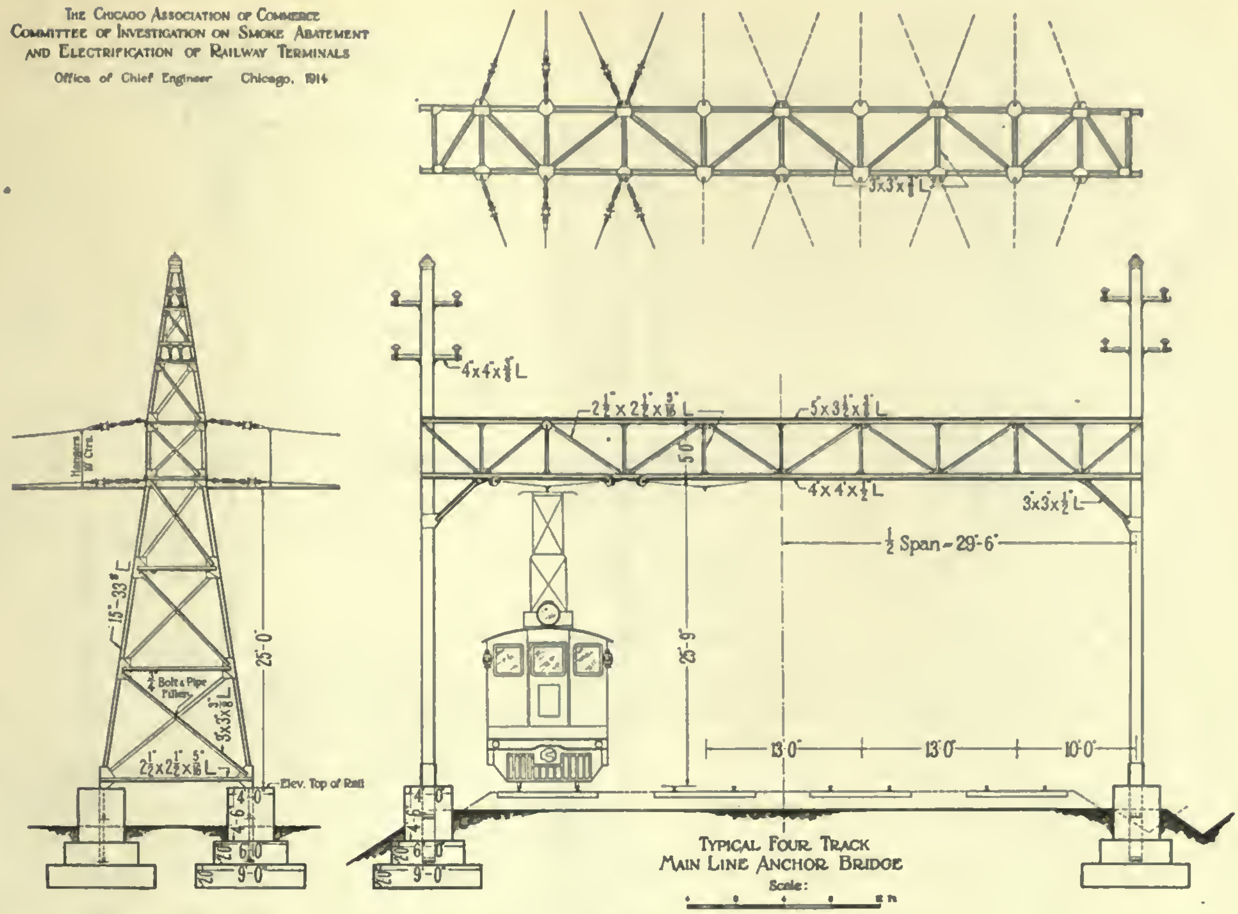

FIG. 638. TYPICAL FOUR TRACK ANCHOR BRIDGE

the cost of transmission system (section 213.012).

Intermediate pull-off poles, either guyed or self-supporting, have been designed for use between supporting structures on curves of more than four degrees. The design of a typical self-supporting pole provided for this purpose is shown by fig. 640.

Supporting Structures for Overhead Contact System for Yard Tracks

For yards having many parallel tracks and sufficient space at the sides for guying, the Committee's specifications provide for cross catenary construction spaced at 300-foot intervals. The supporting structures consist of anchored steel poles at the ends, with intermediate poles between. Where it was not possible to provide for anchoring the end poles, side anchor bridges were specified. The number of intermediate poles is variable. Estimates show that the economical intermediate span is about 250 feet, or a span extending over 20 tracks laid at the usual spacing employed in yards. This was generally reduced, however, since it was found that space is often available for intermediate poles without changing

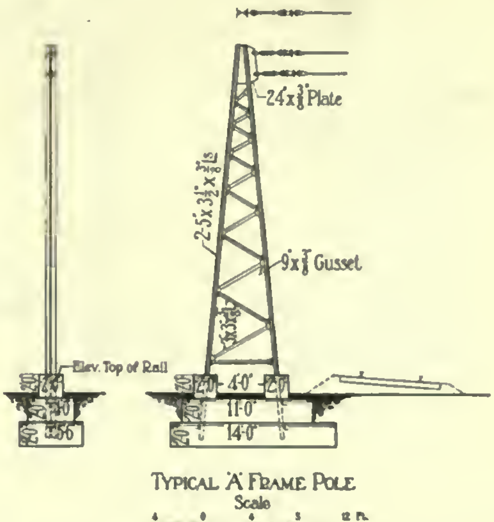

FIG. 640. TYPICAL SELF-SUPPORTING PULL-OFF POLE

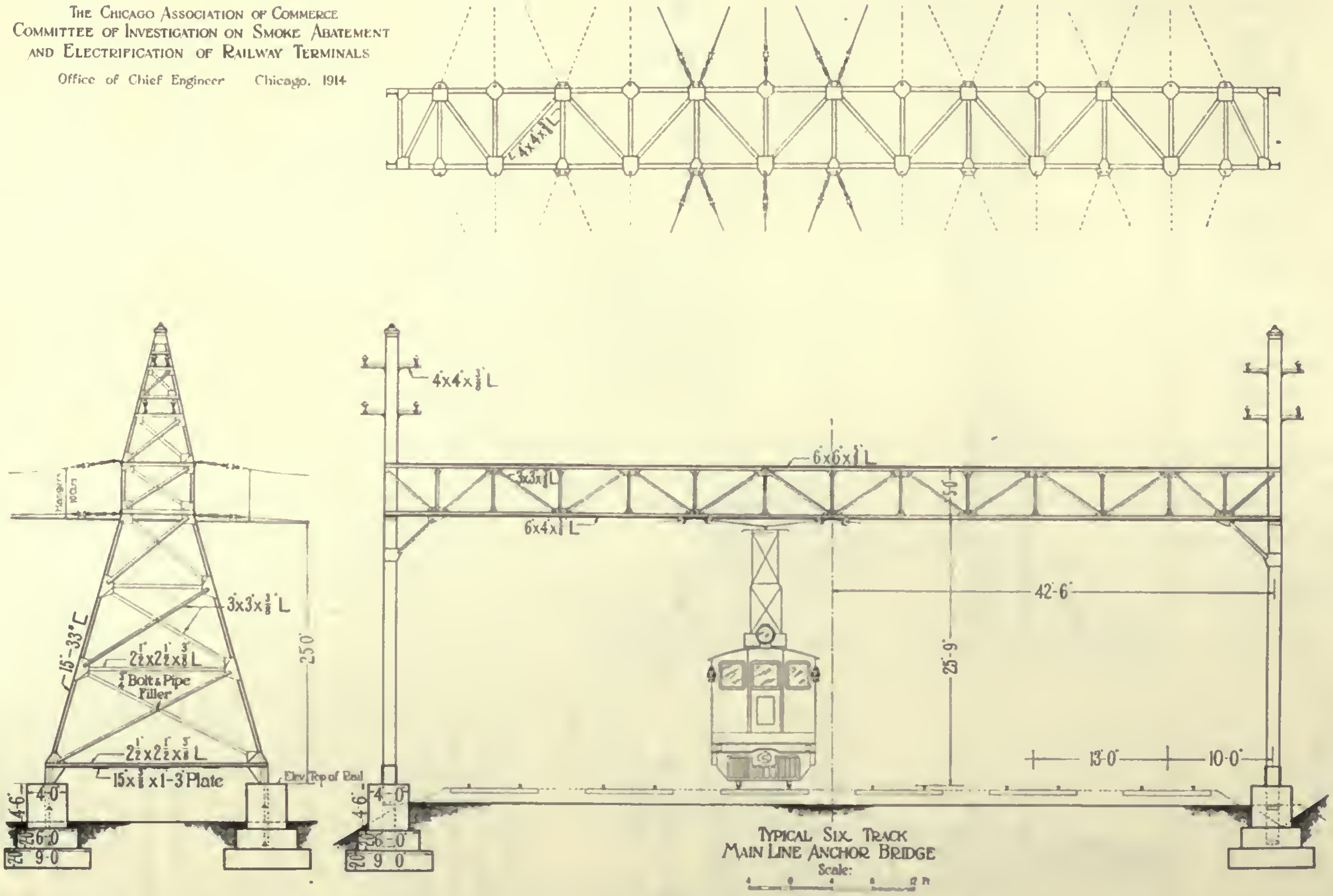

FIG. 639. TYPICAL SIX TRACK ANCHOR BRIDGE

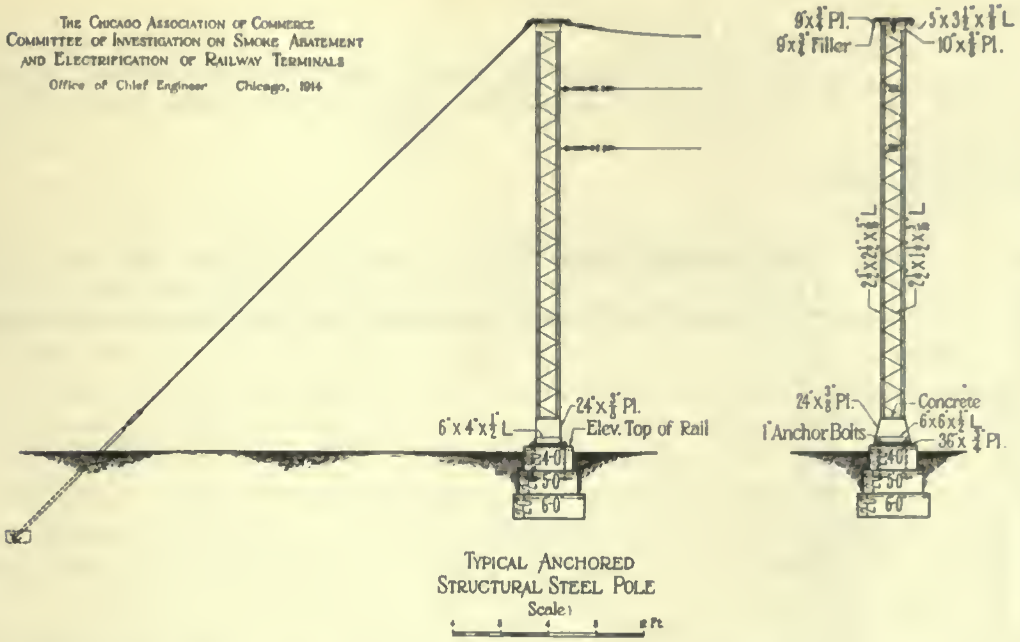

FIG. 641. TYPICAL STRUCTURAL STEEL END POLE FOR CROSS CATENARY YARD TRACK CONSTRUCTION

the track spacing or cutting out tracks. To take advantage of these conditions, it was generally necessary to reduce the span length. The tracks to be abandoned or removed average less than two per cent of the total. Designs of a structural steel end pole, of an intermediate pole and of a side anchor bridge for cross catenary yard track construction are shown by figs. 641 to 643, inclusive.

A typical example of the cross catenary construction provided for yards is shown by fig. 644. This drawing shows an anchored end pole, an intermediate pole and a side anchor bridge set in place to provide support for the overhead contact system for 26 tracks. In this particular case the track spacing was such that it was possible to find the necessary space for all supports without changing track centers or removing any tracks. The four tracks at the left are main tracks and have the secondary messenger and No. 0000 A. W. G. contact wire.

Supporting Structures for Overhead Contact System for Industrial Tracks

The type of supporting structure for the overhead contact system for spur tracks serving industries, upon which estimates have been based, consists of a western cedar pole with a commercial

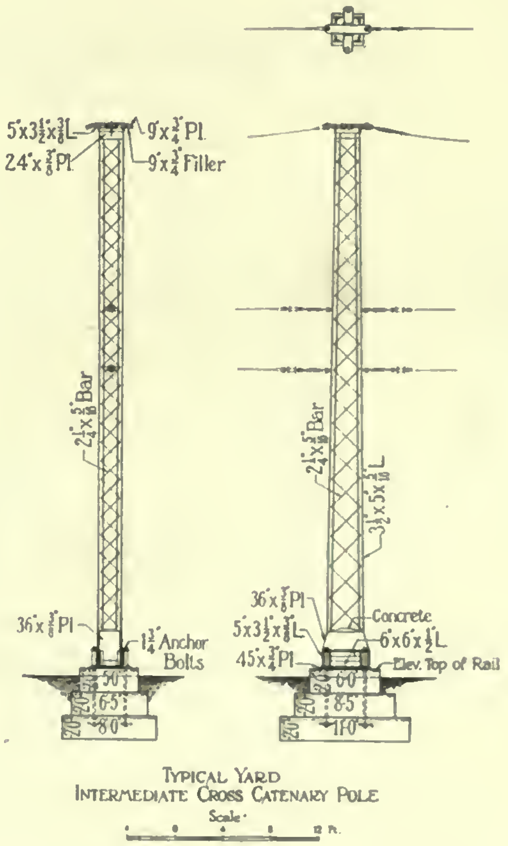

FIG. 642. TYPICAL INTERMEDIATE POLE FOR CROSS CATENARY YARD TRACK CONSTRUCTION

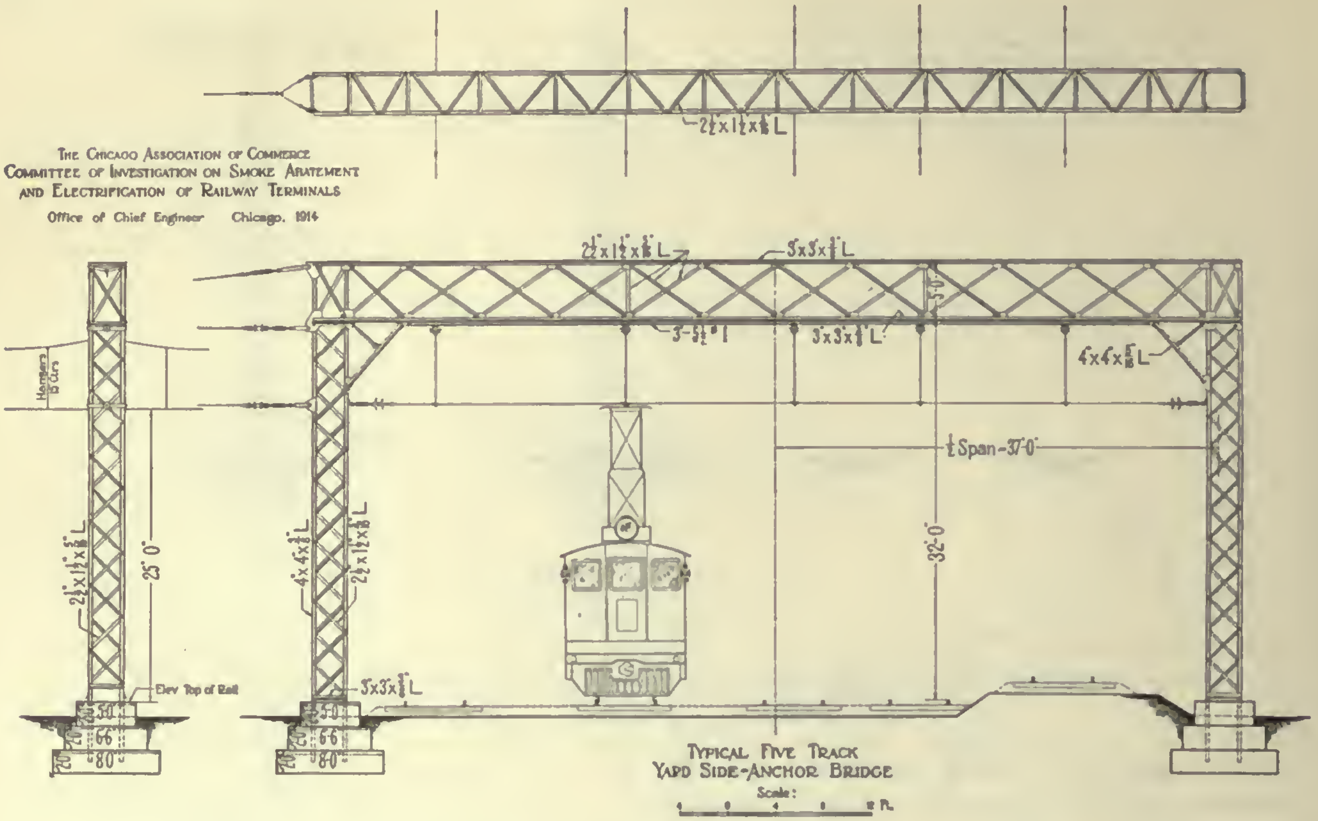

FIG. 643. TYPICAL FIVE TRACK SIDE ANCHOR BRIDGE FOR CROSS CATENARY YARD TRACK CONSTRUCTION

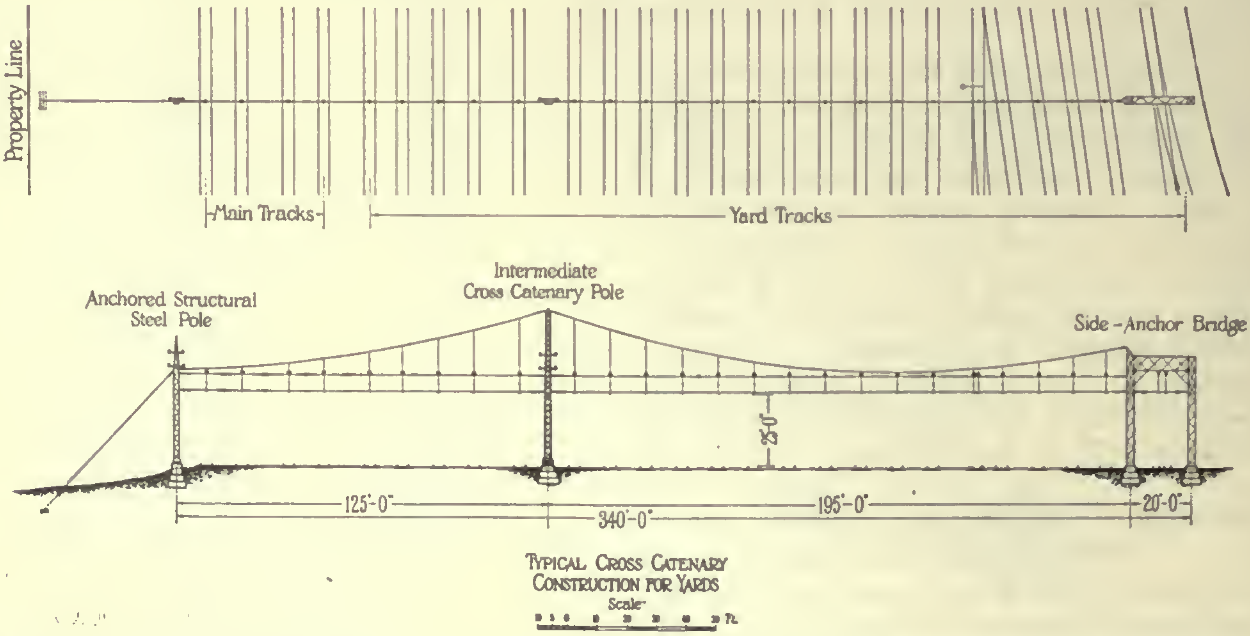

FIG. 644. TYPICAL CROSS CATENARY CONSTRUCTION FOR YARDS, SHOWING ANCHORED END POLE, INTERMEDIATE POLE AND SIDE ANCHOR BRIDGE IN PLACE

form of steel bracket to support the wires. For industrial tracks grouped in small yards of four or five tracks, a span construction with guyed wooden poles has been used for supporting the overhead contact system. In all cases where wooden poles are used, they have been spaced at intervals of 150 feet except where curves or other conditions required a closer spacing. In a few cases where space could not be found for poles, buildings or other structures will serve as supports. Where the number of tracks exceeds five or six, a cross catenary construction with steel supports similar to those used for yard tracks has been specified.

213.026 Materials and Unit Costs for Overhead Contact System for the 11,000-Volt Alternating Current System: The quantity of material and the cost of the labor and material required for the overhead contact system, for 11,000-volt alternating current, have been estimated for each class of track and the average cost per mile of track determined, as a basis for estimating total costs. The quantity of material required for each type of supporting structure for the overhead contact system on main line tracks is shown by table CCLXXVI.

TABLE CCLXXVI. QUANTITY OF MATERIAL REQUIRED FOR DIFFERENT TYPES OF SUPPORTING STRUCTURES FOR MAIN TRACKS, BY NUMBER OF TRACKS SPANNED, 11,000-VOLT A. C. SYSTEM

Type of Supporting Structure	Number of Tracks Spanned	Fig. No.	Total Quantity for Structure not including Anchors and Rods	
			Concrete in Foundation Cubic Yards	Steel Structure Pounds
1	2	3	4	5
Cross catenary span..........	2	631	4.7	3,270
Cross catenary span..........	4	632	6.0	3,930
Cross catenary span..........	6	633	9.7	4,460
Intermediate bridge..........	2	634	9.6	6,250
Intermediate bridge..........	4	635	10.7	10,870
Intermediate bridge..........	6	636	15.7	14,630
Anchor bridge..............	2	637	30.5	10,220
Anchor bridge..............	4	638	45.3	17,670
Anchor bridge..............	6	639	45.3	30,680

The quantity of material required for each type of supporting structure for the overhead contact system for yard tracks is shown by table CCLXXVII.

TABLE CCLXXVII. QUANTITY OF MATERIAL REQUIRED FOR DIFFERENT TYPES OF SUPPORTING STRUCTURES FOR YARD TRACKS. 11,000-VOLT A. C. SYSTEM

Type of Structure	Fig. No.	Total Quantity for Structure not including Anchors and Rods	
		Concrete in Foundation Cubic Yard	Steel Structure Pounds
1	2	3	4
Anchored structural steel pole..........	641	5.7	3,130
Yard intermediate cross catenary pole..	642	12.8	4,810
Five-track yard side anchor bridge......	643	19.4	11,960

The quantity of messenger cable, contact wire, insulators, anchors, fittings and other materials per mile of track was determined for each type of construction.

Prices upon which estimates were based were obtained from quotations and price lists of manufacturing and supply firms. The most important labor items were reduced to cost per mile, while other items of labor incident to special or peculiar conditions were supplied in per cent of total or in fixed amounts from the experience and study of the Committee's engineers.

The base price of copper wire was estimated at $0.1775 per pound at Chicago. The average base price at Chicago for the year 1912 was $0.179 per pound and the average for the ten years from 1904 to 1913, inclusive, was $0.1697.

The cost of both structural steel shapes and tubular steel poles erected and given one coat of paint was estimated at $0.04 per pound.

The cost of concrete foundations in place was estimated at $12.00 per cubic yard.

The cost of wooden poles, 40 feet long with 9-inch tops and treated butts, was estimated at $14.20 each, in place.

The cost of labor for erecting all main track longitudinal wire systems, including steady strains, was estimated at $866 per mile of single track.

The degree to which the several types of construction are adapted to the requirements of the main track overhead contact system under the conditions which exist on the several railroads to be electrified, was determined by laying out the details of construction for representative sections of the main lines of these railroads. The corrected right-of-way plats furnished by the railroads were used for this purpose, and the type of construction best suited to each section of main track within the limits of electrification was determined and tabulated by route elements. To the unit cost per mile of track for supporting structures erected was added the cost per mile of track for the longitudinal wires, insulators and other materials in place. On this basis, the estimated unit costs of labor and material per mile of main track for the overhead contact construction erected and complete, including supporting structures, foundations, line work and anchor bridges, are shown by table CCLXVIII.

Where main tracks pass through or are adjacent to yards, and part of the construction provided for the yard tracks is to be used to support the contact system over the main tracks, the cost of that portion properly belonging to the main tracks was obtained in connection with the cost for the other tracks of the yard.

Estimates were made of the cost of the special work at grade crossings for both 11,000-volt lines and 600-volt trolley lines. Although two anchor bridges have been provided for each such crossing, it has been assumed that in all cases one of these could serve for the adjacent two-mile section and therefore only one was included in the cost of the crossing. The difference between the cost so obtained and the cost of the standard work otherwise required for the trackage involved was taken as the amount to be added for the crossing. These amounts for special work at grade crossings were divided among the different railroads involved, in proportion to the lineal feet of track owned by each railroad, within the limits of the special work included.

On account of the special character of yard construction, it was more difficult to arrive at correct average costs for these tracks than for main tracks. Preliminary to analyzing the unit cost feature, the construction required in 28 yards belonging to 11 different railroads was carefully laid out in complete detail, in order to determine the most satisfactory arrangement and the various kinds of auxiliaries and fittings that would best meet the requirements, and in order also to ascertain to what extent the several yards differed. Both large and small yards were included for classification, make-up, team track, freight house and other work. Finally, 10 yards were selected as typical of all yards to be considered and the cost of the complete contact system determined for each. These yards and the estimated unit costs of labor and materials, per mile, for overhead contact construction complete for main tracks through yards and yard tracks, including supporting structures, foundations, anchors, dead-ends, pull-offs, and line work, are shown by table CCLXXIX, which also includes the unit costs adopted.

The plans of every yard within the limits of electrification were carefully studied and many of the yards were inspected by the Committee's engineers. As a result of this study, the class to which each yard properly belonged was determined. The cost was then found by multiplying the number of miles of main track and of yard track within the yard by the respective unit costs applicable to each. In some cases it was necessary, after classifying a yard, to modify the unit cost because of some essential variation from the standard.

The cost of the overhead contact system for industrial spur tracks was determined by laying out the construction for such tracks on the plans. The cost, including deflectors, dead-ends and other construction not affected by the length, was estimated for various lengths of spurs with average spans of 45 to 90 feet. The estimated costs of 150-foot spans on tangent track, exclusive of deflectors and dead-ends, and that of spans of 45 to 90 feet, including deflectors and dead-ends, are shown by the diagram presented as fig. 645.

For each route element (section 104.05) the number of spurs, number of spans and total length

TABLE CCLXVIII. ESTIMATED UNIT COSTS OF LABOR AND MATERIAL FOR OVERHEAD CONTACT CONSTRUCTION, PER MILE OF MAIN TRACK, 11,000-VOLT A. C. SYSTEM

(Basis of 1912)

Type of Support	Length of Span Feet	Cost per Mile of Single Track				
		2 Tracks	3 Tracks	4 Tracks	5 Tracks	6 Tracks
1	2	3	4	5	6	7
Cross catenary, tubular poles, track in cut or on fill	300	$5,430	$4,800	$4,500	$4,370	$4,330
	250	6,014	5,160	4,914	4,780	4,708
	200	7,174	6,100	5,672	5,440	5,295
Intermediate strut bridge, track in cut or on fill	300	6,120	5,620	5,390	5,230	5,080
	250	6,821	6,257	5,956	5,737	5,579
	200	8,500	7,747	7,201	6,767	6,403
Intermediate strut bridge, supported on retaining walls	300	6,700	6,100	5,780	5,480	5,270
	250	7,518	6,817	6,419	6,097	5,809
	200	9,369	8,477	7,780	7,187	6,090

TABLE CCLXXIX. ESTIMATED COSTS OF LABOR AND MATERIAL FOR OVERHEAD CONTACT CONSTRUCTION FOR TEN TYPICAL RAILROAD YARDS, PER MILE OF TRACK, WITH UNIT COSTS ADOPTED
(Basis of 1912)

Location of Yard	Railroad	Miles of Track			Estimated Cost per Mile of Track		Adopted Unit Cost per Mile of Track	
		Main Track	Yard Track	Total Track	Main Track	Yard Track	Main Track	Yard Track
1	2	3	4	5	6	7	8	9
Western Ave.	Chicago & North Western Ry. and Chicago, Milwaukee & St. Paul Ry.	13.69	55.49	69.18	$4,950	$2,990	$5,000	$3,000
Kolze*	Minneapolis, St. Paul & Sault Ste. Marie Ry.	3.14	14.62	17.76	5,110	2,860	5,100	2,900
12th St. to Randolph St.	Illinois Central R. R. & Michigan Central R. R.	12.03	55.62	67.65	5,500	3,880	5,500	3,900
Robey St. and Carroll Ave.	Pittsburgh, Cincinnati, Chicago & St. Louis Ry., Chicago & North Western Ry. and Chicago, Milwaukee & St. Paul Ry.	7.38	3.78	11.16	5,440	3,670	5,500	3,700
Hayford	Grand Trunk Western Ry.	1.02	1.91	2.03	6,650	4,360	6,700	4,400
Gresham	Chicago, Rock Island & Pacific Ry.	4.44	5.83	10.27	4,780	3,070	4,800	3,100
Indiana Harbor	Baltimore & Ohio R. R.	2.46	2.83	5.29	4,930	3,190	4,900	3,200
North Ave.	Chicago & North Western Ry.	1.11	1.46	2.57	6,260	5,570	6,300	5,600
Diversey Ave.	Chicago & North Western Ry.	....	1.85	1.85	....	3,570	....	3,600
Buffington*	Elgin, Joliet & Eastern Ry.	....	5.42	5.42	....	2,580	....	2,600

* Not to be electrified. Beyond the limits of electrification as finally determined.

of spur track construction were taken from the plans, and the average length of spur and average length of span determined. The cost of contact construction of a spur of this average length and average span was taken from the diagram (fig. 645), and when multiplied by the number of spurs in the element gave the cost of this class of construction in the element involved. This procedure was repeated for all elements having spur tracks.

The unit costs of the overhead contact system for industrial tracks grouped in small yards, were estimated by laying out the construction in detail on the plans of about ten per cent of all such tracks.

A diagram including all costs, except poles and anchors, was prepared to facilitate this work. The cost of poles and anchors was considered separately, as it was possible in some instances to avoid such costs by attaching the cross-spans to buildings or other structures. This diagram of estimated costs for industrial yard tracks is presented as fig. 646.

The estimated unit costs of labor and material for the overhead contact system complete for typical industrial yard tracks, as determined from detailed plans, are shown by table CCLXXX.

The estimates of the remaining 90 per cent of these industrial yard tracks were based upon the unit costs determined from those laid out in detail, by the same general method as that applied to the more important railroad yards.

213.027 Estimated Costs of Labor and Material for Overhead Contact System for the 11,000-Volt Alternating Current System, on the Basis of the Requirements of 1912, Excluding all Allowances for Contingencies and for Engineering: The

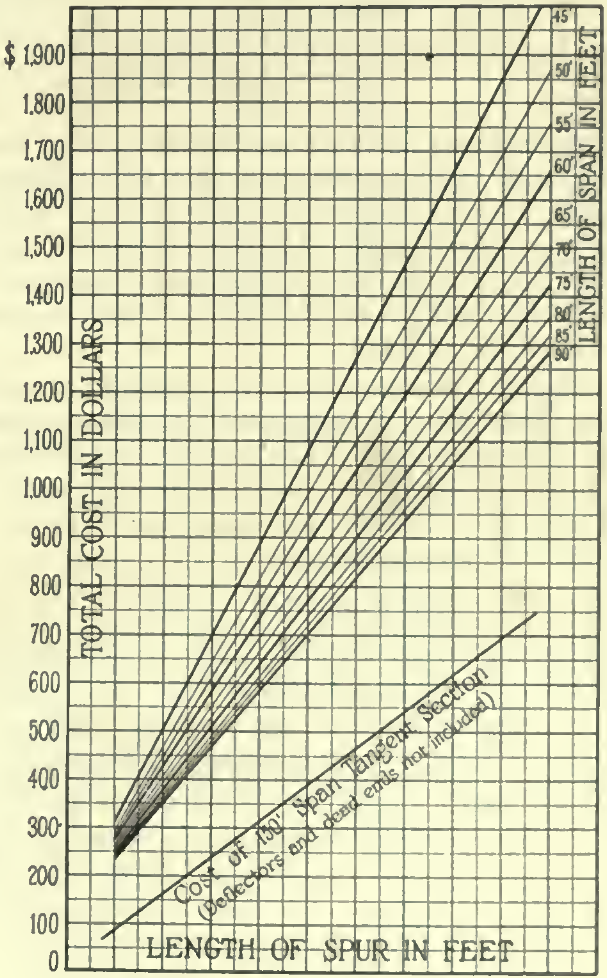

FIG. 645. ESTIMATED COSTS OF INDUSTRIAL SPUR TRACK OVERHEAD CONTACT CONSTRUCTION

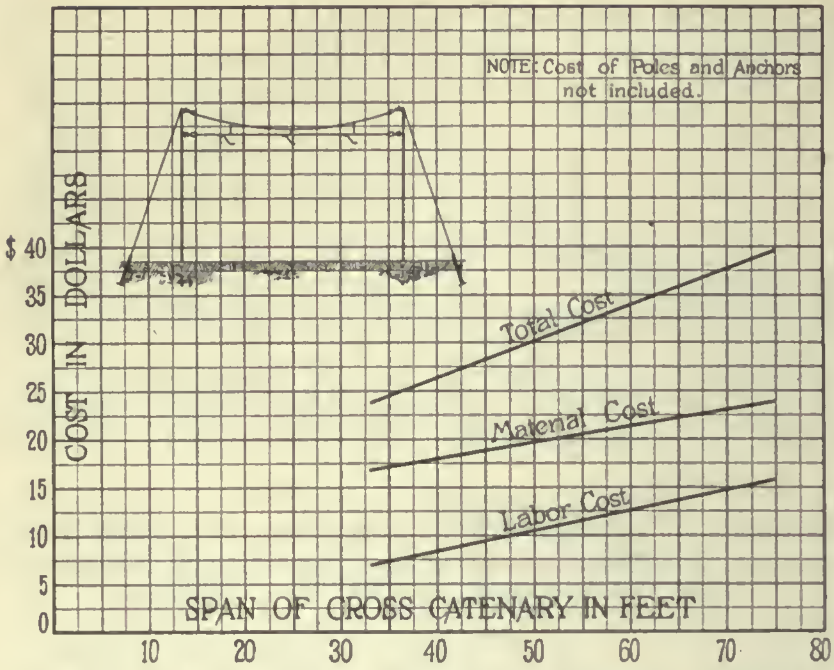

FIG. 646. ESTIMATED COSTS OF INDUSTRIAL TRACK OVERHEAD CONTACT CONSTRUCTION

estimated costs of labor and material, excluding all allowances for contingencies and for engineering, for the overhead contact system for alternating current at 11,000 volts for all tracks to be electrified, by roads and by classes of track, under conditions which obtained in 1912, are shown by table CCLXXXI.

213.028 Overhead Construction for the 2,400-Volt Direct Current System: The types of overhead construction for the 2,400-volt direct current system which have been designed for main tracks, yard tracks and industrial tracks, are described in the following paragraphs.

Main Track Construction

For main tracks the type of construction adopted consists of a $\frac{3}{4}$-inch stranded steel messenger cable supporting a No. 0000 A. W. G. steel secondary messenger, from which are suspended two No. 0000 A. W. G. grooved copper contact wires. The wire construction is otherwise generally similar to that described for the 11,000-volt system. Two contact wires are used for the direct current system in order to give the necessary contact surface required for collecting the greater current at the lower voltage. The messenger cable has been made larger because of the greater load. In those places where this construction does not provide sufficient conductivity, a No. 0000 A. W. G. copper wire has been used instead of a steel wire for the secondary messenger, and bare copper cables of the required cross-section are carried on the extensions to the posts or poles of the supporting structure. The cost of this has been included as a part of the cost of the contact system.

Yard Track Construction

For yard tracks the estimates are based on the use of a single No. 0000 A. W. G. grooved copper contact wire supported from a $\frac{7}{16}$-inch stranded steel messenger cable. The wire construction is otherwise generally similar to that described for the 11,000-volt system.

Industrial Track Construction

For industrial spur and yard tracks, a type of construction has been used for the basis of the estimates which differs from that described for the 11,000-volt system only in that a No. 0000 A. W. G. copper contact wire has been substituted for a No. 00 A. W. G. copper wire.

213.029 Supporting Structures for Overhead Contact for the 2,400-Volt Direct Current System: Structures have been designed for supporting the 2,400-volt direct current overhead construction

TABLE CCLXXX. ESTIMATED UNIT COSTS OF LABOR AND MATERIAL FOR OVERHEAD CONTACT SYSTEM FOR INDUSTRIAL YARD TRACKS

(Basis of 1912)

Location of Yard	Industry	Description	Miles of Track	Estimated Cost per Mile of Track
1	2	3	4	5
Ashland Ave. and 43d St.	Swift & Co.	4 or 5 parallel tracks between buildings.	2.27	$2,800
Morgan St. between 45th and 46th sts.	Arms Palace Car Co.	Fan shaped yard and some buildings	3.00	2,800
106th St. and Torrence Ave.	Wisconsin Steel Co.	Combination spur and yard tracks	4.00	4,100

TABLE CCLXXXI. ESTIMATED COSTS OF LABOR AND MATERIAL FOR OVERHEAD CONTACT SYSTEM, BY ROADS, 11,000-VOLT A. C. SYSTEM

(Basis of 1912)

Railroad	Main Tracks	Other Tracks	Adjacent Industrial Tracks Privately Owned	Total for All Tracks
1	2	3	4	5
Atchison, Topeka & Santa Fe Ry	$ 161,218	$170,574	$ 23,130	$ 354,922
Baltimore & Ohio R. R	189,641	82,675	5,100	277,416
Baltimore & Ohio Chicago Terminal R. R	397,007	155,411	29,100	581,518
Calumet, Hammond & Southeastern R. R	0	24,200	0	24,200
Chesapeake & Ohio Ry. of Indiana	0	650	0	650
Chicago & Alton R. R	106,645	131,739	13,100	251,484
Chicago & Calumet River R. R	0	13,900	53,580	67,480
Chicago & Eastern Illinois R. R	9,683	62,771	4,329	76,783
Chicago & Erie R. R	34,066	90,685	1,035	125,786
Chicago & North Western Ry	1,357,479	878,494	39,554	2,275,527
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	769,689	538,959	69,111	1,377,759
Chicago, Burlington & Quincy R. R	409,680	312,697	70,566	792,943
Chicago Great Western R. R	3,981	60,000	180	64,161
Chicago, Indiana & Southern R. R	59,844	9,082	0	68,926
Chicago, Indianapolis & Louisville Ry	25,263	6,308	0	31,571
Chicago Junction Ry	245,380	407,773	127,614	780,767
Chicago, Milwaukee & St. Paul Ry	588,792	459,704	78,093	1,126,589
Chicago River & Indiana R. R	25,092	3,510	15,050	43,652
Chicago, Rock Island & Pacific Ry	406,440	224,334	0	630,774
Chicago Short Line Ry	0	3,004	19,536	22,540
Chicago Union Transfer Ry	43,560	8,220	650	52,430
Chicago, West Pullman & Southern R. R	0	11,709	62,741	74,450
Elgin, Joliet & Eastern Ry	32,983	390,104	10,015	433,102
Grand Trunk Western Ry	122,196	119,600	26,220	268,016
Illinois Central R. R	844,930	555,242	18,773	1,418,945
Illinois Northern Ry	33,780	26,678	28,702	89,160
Indiana Harbor Belt R. R	141,285	3,175	0	144,460
Lake Shore & Michigan Southern Ry	506,972	211,279	4,240	722,491
Michigan Central R. R	137,090	141,778	4,570	283,438
Minneapolis, St. Paul & Sault Ste. Marie Ry*	....	....	....	....
New York, Chicago & St. Louis R. R	165,102	83,379	0	248,481
Pere Marquette R. R	0	29,100	0	29,100
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	342,192	260,642	23,864	626,698
Pittsburgh, Fort Wayne & Chicago Ry	652,650	292,109	58,585	1,003,344
Pullman Railroad	47,605	32,631	110,292	190,528
Wabash Railroad	114,925	163,835	2,139	280,899
Totals	$7,975,170	$5,965,951	$899,869	$14,840,990

* Owns no track to be electrified.

over each class of track, and these have served as the basis of the estimates of cost. They are of the same type as those already described for the 11,000-volt alternating current system (figs. 631 to 643, inclusive) and the same spacing has been used. The details and members of main track bridges are heavier, and the diameters of the tubular poles for cross catenary construction have been increased to provide for the greater dead loads imposed by the heavier catenary construction, the greater wind loads and, on curves, the greater side loads caused by increased tension. For yard tracks the increased dead loads and tensions are taken care of by increasing the heights of intermediate poles and providing heavier members for all structures. For industrial spur tracks and small industrial yards, structures identical with those described for the 11,000-volt system have been used. For large industrial yards, structures similar to those described for 2,400-volt yard tracks have been used. The concrete foundations required for the 2,400-volt structures are in nearly all cases larger than for the 11,000-volt structures.

Use Made of Existing Structures

Provision has been made for the use of existing signal bridges as described for 11,000 volts, but in addition to raising them it has been necessary to provide for strengthening the bridge legs, and the cost of this work has been included in the estimates.

213.030 Materials and Unit Costs for Overhead Contact for the 2,400-Volt Direct Current System: The quantity of material required for each type of supporting structure for the 2,400-volt direct current system has been estimated for main tracks as shown by table CCLXXXII.

The quantity of material required for each type of supporting structure for the overhead contact system for yard tracks is shown by table CCLXXXIII.

TABLE CCLXXXII. QUANTITY OF MATERIAL REQUIRED FOR DIFFERENT TYPES OF SUPPORTING STRUCTURES FOR MAIN TRACKS, 2,400-VOLT D. C. SYSTEM

Type of Supporting Structure	Number of Tracks Spanned	Fig. No.	Total Quantity for Structure not including Anchors and Rods	
			Concrete in Foundation Cubic Yards	Steel Structure Pounds
1	2	3	4	5
Cross catenary span...........	2	631	4.7	3,270
Cross catenary span...........	4	632	9.1	4,000
Cross catenary span...........	6	633	13.4	5,000
Intermediate bridge...........	2	634	11.3	9,110
Intermediate bridge...........	4	635	14.8	13,940
Intermediate bridge...........	6	636	19.5	20,100
Anchor bridge................	2	637	33.0	11,400
Anchor bridge................	4	638	49.3	19,580
Anchor bridge................	6	639	52.8	39,280

TABLE CCLXXXIII. QUANTITY OF MATERIAL REQUIRED FOR DIFFERENT TYPES OF SUPPORTING STRUCTURES FOR YARD TRACKS, 2,400-VOLT D. C. SYSTEM

Type of Structure	Fig. No.	Total Quantity for Structure not including Anchors and Rods	
		Concrete in Foundations Cubic Yards	Steel Structures Pounds
1	2	3	4
Anchored structural steel pole.....	641	5.8	3,160
Yard intermediate cross catenary pole..................	642	13.1	5,050
Five track yard side anchor bridge	643	20.4	12,550

The prices of materials for the 11,000-volt system have been used also in the estimates for the 2,400-volt system.

The cost of labor for erecting main track longitudinal wire systems, including steady strains, was estimated at $1,088 per mile of single track.

In the same manner as previously described for the 11,000-volt system, the costs of labor and material per mile of main track for the 2,400-volt overhead contact construction erected and complete were estimated as shown by table CCLXXXIV.

The unit cost of labor and material per mile of track for 2,400-volt direct current overhead contact construction, erected and complete, was estimated, for the ten typical yards selected, as shown by table CCLXXXV, which also shows the unit costs adopted.

These unit costs were applied to other yards to obtain their cost, in the manner described for the 11,000-volt alternating current system (section 213.026).

The cost of the 2,400-volt overhead construction for industrial spurs and yards has been estimated at $257 per mile more than for the 11,000-volt construction. This addition covers the cost of the larger contact wire required.

213.031 Estimated Costs of Labor and Material for Overhead Contact for the 2,400-Volt Direct Current System on the Basis of the Requirements of 1912, Excluding all Allowances for Contingencies and for Engineering: The estimated costs of labor and material, excluding all allowances for contingencies and for engineering, for the overhead contact 2,400-volt direct current system, for all tracks to be electrified, under the conditions which obtained in 1912, are set forth by roads and by classes of track in table CCLXXXVI.

213.032 Estimated Total Cost of the Overhead Contact System: The estimated total cost of the overhead contact system for the electric operation of the Chicago railroad terminals is based on the cost of labor and materials as determined for 1912, extended in a manner normal to these estimates (chapter 212), the factors of extension in this case being as follows:

	PER CENT
1. To cover growth in mileage of railroads, December 31, 1912, to December 31, 1922	30.0
2. Contingencies	20.0
3. Engineering, design, supervision and administration	10.0
4. Interest, insurance and taxes during construction, at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

TABLE CCLXXXIV. ESTIMATED UNIT COSTS OF LABOR AND MATERIAL FOR OVERHEAD CONTACT CONSTRUCTION, PER MILE OF MAIN TRACK, 2,400-VOLT D. C. SYSTEM

(Basis of 1912)

Type of Support	Length of Span Feet	Cost per Mile of Single Track				
		2 Tracks	3 Tracks	4 Tracks	5 Tracks	6 Tracks
1	2	3	4	5	6	7
Cross catenary, tubular poles, track in cut or on fill........	300 250 200	$ 6,003 6,831 7,743	$ 5,610 6,380 7,080	$5,373 6,025 6,743	$5,240 5,780 6,495	$5,173 5,667 6,294
Intermediate strut bridge, track in cut or on fill	300 250 200	7,829 9,587 11,207	6,945 8,310 9,650	6,643 7,660 8,794	6,500 7,470 8,525	6,431 7,377 8.428
Intermediate strut bridge supported on existing retaining walls	300 250 200	8,432 10,284 12.077	7,270 8,780 10.210	6,928 8,123 9.374	6,740 7,720 8,860	6,623 7,468 8,555

TABLE CCLXXXV. ESTIMATED UNIT COSTS OF LABOR AND MATERIAL FOR OVERHEAD CONTACT CONSTRUCTION FOR TEN TYPICAL RAILROAD YARDS, PER MILE OF TRACK, 2,400-VOLT D. C. SYSTEM

(Basis of 1912)

Location of Yard	Railroad	Miles of Track			Estimated Cost per Mile of Track		Adopted Unit Cost per Mile of Track	
		Main Track	Yard Track	Total Track	Main Track	Yard Track	Main Track	Yard Track
1	2	3	4	5	6	7	8	9
Western Avenue...	Chicago & North Western Railway and Chicago, Milwaukee & St. Paul Railway	13.69	55.49	69.18	$5,690	$3,365	$5,700	$3,400
Kolze*...........	Minneapolis, St. Paul & Sault Ste. Marie Railway	3.14	14.62	17.76	6,200	3,215	6,200	3,200
12th Street to Randolph Street	Illinois Central Railroad and Michigan Central Railroad	12.03	55.62	67.65	6,760	4,295	6,760	4,300
Robey Street......	Pittsburgh, Cincinnati, Chicago & St. Louis Railway, Chicago & North Western Railway and Chicago, Milwaukee & St. Paul Railway	7.38	3.78	11.16	6,800	4,110	6,800	4,100
Hayford..........	Grand Trunk Western Railway	1.02	1.91	2.93	8,100	4,820	8,100	4,800
Gresham..........	Chicago, Rock Island & Pacific Railway	4.44	5.83	10.27	5,800	3,458	5,800	3,500
Indiana Harbor ...	Baltimore & Ohio Railroad	2.46	2.83	5.29	5,480	3,589	5,500	3,600
North Avenue.....	Chicago & North Western Railway	1.11	1.46	2.57	7,950	6,100	8,000	6,100
Diversey Avenue..	Chicago & North Western Railway	....	1.85	1.85	....	3,910	....	3,910
Buffington*.......	Elgin, Joliet & Eastern Railway	....	5.42	5.42	...	2,908	....	3,000

* Not to be electrified. Beyond the limits of electrification as finally determined.

TABLE CCLXXXVI. ESTIMATED TOTAL COST OF LABOR AND MATERIAL FOR OVERHEAD CONTACT SYSTEM, BY ROADS, 2,400-VOLT D. C. SYSTEM

(Basis of 1912)

Railroad	Main Tracks	Other Tracks	Adjacent Industrial Tracks Privately Owned	Total for All Tracks
1	2	3	4	5
Atchison, Topeka & Santa Fe Railway	$ 201,408	$ 191,330	$ 24,690	$ 417,428
Baltimore & Ohio Railroad	245,075	92,710	5,386	343,171
Baltimore & Ohio Chicago Terminal Railroad	511,119	171,725	31,302	714,146
Calumet, Hammond & Southeastern Railroad	0	25,717	0	25,717
Chesapeake & Ohio Railway of Indiana	0	696	0	696
Chicago & Alton Railroad	138,148	144,057	13,800	296,005
Chicago & Calumet River Railroad	0	15,150	58,180	73,330
Chicago & Eastern Illinois Railroad	12,200	69,940	4,630	86,770
Chicago & Erie Railroad	45,695	102,220	1,108	149,023
Chicago & North Western Railway	1,785,789	974,480	41,962	2,802,231
Chicago & Western Indiana Railroad and the Belt Railway of Chicago	994,895	610,215	73,252	1,678,362
Chicago, Burlington & Quincy Railroad	536,149	342,070	77,016	955,235
Chicago Great Western Railroad	5,240	67,852	190	73,282
Chicago, Indiana & Southern Railroad	72,648	10,040	0	82,688
Chicago, Indianapolis & Louisville Railway	30,814	6,972	0	37,786
Chicago Junction Railway	309,917	450,213	136,494	896,624
Chicago, Milwaukee & St. Paul Railway	773,585	511,960	82,643	1,368,188
Chicago River & Indiana Railroad	30,908	3,798	16,030	50,736
Chicago, Rock Island & Pacific Railway	521,510	248,212	0	769,722
Chicago Short Line Railway	0	3,214	20,742	23,956
Chicago Union Transfer Railway	50,999	9,160	689	60,848
Chicago, West Pullman & Southern Railroad	0	12,882	66,603	79,485
Elgin, Joliet & Eastern Railway	40,610	415,443	10,700	466,753
Grand Trunk Western Railway	153,481	133,878	27,800	315,159
Illinois Central Railroad	1,099,295	600,958	19,947	1,720,200
Illinois Northern Railway	43,318	28,967	31,100	103,385
Indiana Harbor Belt Railroad	176,161	3,500	0	179,661
Lake Shore & Michigan Southern Railway	682,748	226,444	4,500	913,692
Michigan Central Railroad	172,568	158,906	4,930	336,404
Minneapolis, St. Paul & Sault Ste. Marie Railway*	......	......	......	......
New York, Chicago & St. Louis Railroad	208,940	97,336	0	306,276
Pere Marquette Railroad	0	32,950	0	32,950
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	431,239	284,914	25,239	741,392
Pittsburgh, Fort Wayne & Chicago Railway	832,142	326,450	61,896	1,220,488
Pullman Railroad	61,150	35,340	118,005	214,495
Wabash Railroad	152,055	180,700	6,519	339,274
Totals	$10,319,806	$6,590,399	$965,353	$17,785,558

* Owns no track to be electrified.

The values thus derived may be accepted as the total costs on the basis of 1922. The estimated total costs by railroads of the overhead contact system for both the 2,400-volt direct current and the 11,000-volt alternating current systems are set forth by table CCLXXXVII.

TABLE CCLXXXVII. ESTIMATED TOTAL COSTS OF OVERHEAD CONTACT SYSTEM, BY ROADS, 2,400-VOLT D. C. SYSTEM AND 11,000-VOLT A. C. SYSTEM
(Dec. 31, 1922)

Railroad	2,400-Volt D. C.	11,000-Volt A. C.
Atchison, Topeka & Santa Fe Ry.	$ 791,519	$ 672,996
Baltimore & Ohio R. R.	650,714	526,031
Baltimore & Ohio Chicago Terminal R. R.	1,354,149	1,102,662
Calumet, Hammond & Southeastern R. R.	48,764	45,888
Chesapeake & Ohio Ry. of Indiana	1,320	1,233
Chicago & Alton R. R.	561,279	476,859
Chicago & Calumet River R. R.	139,047	127,954
Chicago & Eastern Illinois R. R.	164,532	145,594
Chicago & Erie R. R.	282,574	238,513
Chicago & North Western Ry.	5,313,534	4,314,809
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	3,182,476	2,612,479
Chicago, Burlington & Quincy R. R.	1,811,297	1,503,563
Chicago Great Western R. R.	138,956	121,661
Chicago, Indiana & Southern R. R.	156,791	130,696
Chicago, Indianapolis & Louisville Ry.	71,649	59,864
Chicago Junction Ry.	1,700,160	1,480,475
Chicago, Milwaukee & St. Paul Ry.	2,594,331	2,136,215
Chicago River & Indiana R. R.	96,205	82,772
Chicago, Rock Island & Pacific Ry.	1,459,531	1,196,061
Chicago Short Line Ry.	45,425	42,740
Chicago Union Transfer Ry.	115,379	99,417
Chicago, West Pullman & Southern R. R.	150,718	141,171
Elgin, Joliet & Eastern Ry.	885,048	821,239
Grand Trunk Western Ry.	597,598	508,207
Illinois Central R. R.	3,261,809	2,690,575
Illinois Northern Ry.	196,037	169,063
Indiana Harbor Belt R. R.	340,670	273,922
Lake Shore & Michigan Southern Ry.	1,732,524	1,369,973
Michigan Central R. R.	637,883	537,449
Minneapolis, St. Paul & Sault Ste. Marie Ry.*	......	......
New York, Chicago & St. Louis R. R.	580,754	471,165
Pere Marquette R. R.	62,479	55,179
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	1,405,813	1,188,332
Pittsburgh, Ft. Wayne & Chicago Ry.	2,314,265	1,902,521
Pullman Railroad	406,721	361,275
Wabash Railroad	643,325	532,635
Totals	$33,895,276	$28,141,188

*Owns no track to be electrified.

BRIDGE WARNINGS

213.033 Description and Location: It has been shown (section 213.023), that the overhead contact wire cannot always be maintained at sufficient height to permit employes to ride with safety on the tops of all freight cars, and that provision must be made for the protection of trainmen either through the agency of some type of warning device or the enforcement of rigid regulations applying to specific locations or districts. The usual form of low-bridge warning used on steam operated roads consists of a number of light rods, ropes or wires hung vertically above the track from a cross wire or cable spanning a number of tracks, or from a pole and bracket in the case of one track. This form of warning has not been found satisfactory for electric operation since the pantograph shoe, when passing through the ropes or rods at high speed, bends or breaks them. While no details of design are here presented, it is believed that a satisfactory device can be developed for this purpose. It has been assumed, in preparing these estimates, that on main line tracks where high speeds may be expected, automatic warnings are to be used in which the arm or other support, from which the warning devices are hung, will be hinged and operated by mechanism controlled by track circuits in some such manner as are the present automatic block signals. The automatic control exercised will be such that at the approach of a locomotive the support will be displaced from the path of the pantograph and immediately after the locomotive has passed will swing back into position above the train.

For yard and other tracks where trains are not operated at high speeds, it is assumed that mechanical warnings not unlike the present type of low-bridge warning will be used. In such cases rods of light bamboo or similar material, which may be deflected but not injured by the moving pantograph, may be used. The supporting span or bracket is to be insulated for the line voltage employed.

When obstructions are so close that the contact wire rising from under one obstruction must be depressed for the next before reaching the normal height of 24 feet, 2 inches, no warning is to be used between obstructions, as it is assumed that employes will be instructed to keep off the tops of cars in such places.

Since any overhead obstruction less than 25 feet in the clear requires the wire to be depressed below the standard height, the number of overhead obstructions not requiring warnings will be few. Signal bridges are to be raised and are to serve as supports for the contact system and hence will require no warnings. It has been assumed that the 600-volt trolley wires which cross electrified tracks of railroads at grade cannot be raised to the required height without introducing difficulties in the operation with pole and wheel trolleys, so the higher voltage contact wires of the railroad must be depressed to the level of the existing trolley wires. Warning devices have therefore been included for all such crossings. In and around industrial plants, there are many obstructions such as building portals, foot bridges, runways and pipes, which are and must remain below 25 feet, and warnings have been provided for these. Probably many obstructions of this class can be so altered as to make warnings unnecessary, but the cost of the change would probably more than offset the cost of the warning, and the cost of warnings for all obstructions that are of record has therefore been included in making up this estimate of cost.

213.034 Unit Cost: The cost of labor and material for installing the automatic device for main tracks has been estimated at $500 per track for one side of an obstruction, and that for installing the non-automatic warning has been estimated at $50.00. The number of warnings and their estimated cost is the same for both 2,400-volt direct current and 11,000-volt alternating current contact systems.

213.035 Estimated Costs of Labor and Material: The estimated costs of labor and material for the bridge warnings required for both the 2,400-volt direct current and the 11,000-volt alternating current systems for all tracks to be electrified, based upon conditions which obtained in 1912, are shown for each road and for each kind of track in table CCLXXXVIII.

TABLE CCLXXXVIII. ESTIMATED COSTS OF LABOR AND MATERIAL FOR BRIDGE WARNINGS FOR OVERHEAD CONTACT SYSTEM, BY ROADS, 2,400-VOLT D. C. SYSTEM AND 11,000-VOLT A. C. SYSTEM
(Basis of 1912)

Railroad	Main Tracks	All Other Tracks	Total
1	2	3	4
Atchison, Topeka & Santa Fe Ry.	$ 19,000	$ 1,700	$20,700
Baltimore & Ohio R. R.	10,000	3,100	13,100
Baltimore & Ohio Chicago Terminal R. R.	37,000	2,900	39,900
Calumet, Hammond & Southeastern R. R.	0	0	0
Chesapeake & Ohio Ry. of Indiana	0	0	0
Chicago & Alton R. R.	5,000	1,100	6,100
Chicago & Calumet River R. R.	0	0	0
Chicago & Eastern Illinois R. R.	2,000	0	2,000
Chicago & Erie R. R.	4,000	0	4,000
Chicago & North Western Ry.	59,000	7,450	66,450
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	61,000	6,050	67,050
Chicago, Burlington & Quincy R. R.	26,000	4,650	30,650
Chicago Great Western R. R.	16,000	0	16,000
Chicago, Indiana & Southern R. R.	6,000	0	6,000
Chicago, Indianapolis & Louisville Ry.	2,000	450	2,450
Chicago Junction Ry.	15,000	9,100	24,100
Chicago, Milwaukee & St. Paul Ry.	39,000	9,400	48,400
Chicago River & Indiana R. R.	2,000	0	2,000
Chicago, Rock Island & Pacific Ry.	32,000	2,650	34,650
Chicago Short Line Ry.	3,500	650	4,150
Chicago Union Transfer Ry.	1,000	0	1,000
Chicago, West Pullman & Southern R. R.	0	1,300	1,300
Elgin, Joliet & Eastern Ry.	7,500	4,450	11,950
Grand Trunk Western Ry.	4,000	300	4,300
Illinois Central R. R.	118,000	1,800	119,800
Illinois Northern Ry.	2,000	800	2,800
Indiana Harbor Belt R. R.	6,000	200	6,200
Lake Shore & Michigan Southern Ry.	20,000	1,100	21,100
Michigan Central R. R.	13,000	450	13,450
Minneapolis, St. Paul & Sault Ste. Marie Ry*.	......	......	......
New York, Chicago & St. Louis R. R.	14,000	300	14,300
Pere Marquette R. R.	0	0	0
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	26,000	3,900	29,900
Pittsburgh, Fort Wayne & Chicago Ry.	33,500	4,150	37,650
Pullman R. R.	0	0	0
Wabash R. R.	4,000	750	4,750
Totals	$587,500	$68,700	$656,200

* Owns no track to be electrified.

213.036 Estimated Total Cost of Bridge Warnings: The estimated total cost of bridge warnings for the electric operation of the Chicago railroad terminals is based on the cost of labor and materials as determined for 1912, extended in a manner normal to these estimates (chapter 212), the factors of extension in this case being as follows:

	PER CENT
1. To cover growth in mileage of railroads, at 3.0 per cent per annum for 4 years, December 31, 1912, to December 31, 1916	12.0
2. Contingencies	20.0
3. Engineering, design, supervision and administration	10.0
4. Interest, insurance and taxes during construction, at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

The values thus derived may be accepted as the total cost on the basis of the requirements of 1922. The estimated total costs by railroads of the bridge warnings for both the 2,400-volt direct current and the 11,000-volt alternating current systems are set forth by table CCLXXXIX.

RETURN CIRCUIT

213.037 General Considerations: The term "return circuit" as herein used refers to the means by which electric current is returned from the motive power units to the substations. Under the plan of the Committee, the track rails will be used for the return circuit. In order to fit them for this purpose the track rails must be bonded at joints and connected to the substations. The cost of the return circuit, therefore, will include the cost of the following items.

1. Track bonding, or electrically connecting rail ends at joints.

2. Cross bonding, or electrically connecting the rails of adjacent tracks.

3. Substation connections, or electrically connecting the track rails to the substation bus-bars.

TABLE CCLXXXIX. ESTIMATED TOTAL COST OF BRIDGE WARNINGS FOR OVERHEAD CONTACT SYSTEM, BY ROADS, 2,400-VOLT D. C. SYSTEM AND 11,000-VOLT A. C. SYSTEM
(Dec. 31, 1922)

Railroad	Total Cost
Atchison, Topeka & Santa Fe Ry.	$ 33,816
Baltimore & Ohio R. R.	21,401
Baltimore & Ohio Chicago Terminal R. R.	65,182
Calumet, Hammond & Southeastern R. R.	0
Chesapeake & Ohio Ry. of Indiana	0
Chicago & Alton R. R.	9,965
Chicago & Calumet River R. R.	0
Chicago & Eastern Illinois R. R.	3,267
Chicago & Erie R. R.	6,535
Chicago & North Western Ry.	108,554
Chicago & Western Indiana R.R. and the Belt Ry. of Chicago.	109,534
Chicago, Burlington & Quincy R. R.	50,071
Chicago Great Western R. R.	26,138
Chicago, Indiana & Southern R. R.	9,802
Chicago, Indianapolis & Louisville Ry.	4,002
Chicago Junction Ry.	39,371
Chicago, Milwaukee & St. Paul Ry.	79,068
Chicago River & Indiana R. R.	3,267
Chicago, Rock Island & Pacific Ry.	56,605
Chicago Short Line Ry.	6,780
Chicago Union Transfer Ry.	1,634
Chicago, West Pullman & Southern R. R.	2,124
Elgin, Joliet & Eastern Ry.	19,522
Grand Trunk Western Ry.	7,025
Illinois Central R. R.	195,708
Illinois Northern Ry.	4,574
Indiana Harbor Belt R. R.	10,129
Lake Shore & Michigan Southern Ry.	34,470
Michigan Central R. R.	21,972
Minneapolis, St. Paul & Sault Ste. Marie Ry*	......
New York, Chicago & St. Louis R. R.	23,361
Pere Marquette R. R.	0
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	48,846
Pittsburgh, Fort Wayne & Chicago Ry.	61,506
Pullman R. R.	0
Wabash R. R.	7,760
Total	$1,071,989

* Owns no tracks to be electrified.

The characteristics of these features, upon which are based the estimates of cost, are described in the sections which follow.

213.038 Track Bonding: In formulating an estimate of the cost of bonding the tracks of the Chicago railroad terminals, no attempt has been made to specify the precise character of the bond to be used for each particular situation. The bonding of existing tracks adds a new detail to existing structures, making standardization difficult. There are many different rail sections and many designs of joints to be dealt with, and the standards of track maintenance vary. Experience with the bonds now used in connection with the signal track circuits suggests that were larger bonds, such as are required for electric traction, placed around the joints without protection, they would be subject to theft. On the other hand, a very short bond even when exposed offers little incentive to thieves because the scrap value of the copper which it yields is small compared with the difficulty of its removal; but a short bond, while perhaps secure against theft, is not sufficiently flexible to withstand the vibration occasioned by the passage of heavy equipment over joints in tracks which are not kept in good condition, as is usually the case on yard tracks and, in fact, on all tracks except those of the best maintained main lines. Inspections of the tracks have shown that while splice bars are occasionally found which provide sufficient space between the bars and web of the rail to accommodate a bond of the required size and thus to give perfect protection to the bond, such bars are not extensively used. New splice bars will, therefore, generally be required if protected bonds are to be used, and as it is always difficult to remove old bars without ruining the bolts, new bolts also will be necessary. The removed bars, if of a modern type still standard on the road, will be serviceable for tracks beyond the limits of electrification, but the cost of sorting, storing and re-distributing will tend to reduce their service value to such an extent that it will not be appreciably more than that of scrap.

In view of the considerations already set forth, and also of the fact that the Committee is concerned with the cost of bonding rather than with the design of bonds, it has been deemed sufficient to base the estimates of the cost of track bonding on the assumption that all bonds are to be of the protected type, installed under new splice bars with new bolts. The cost of the new bars and bolts, less the scrap value of those removed, and the cost of labor are included in the total cost of bonding. The cost thus obtained is in most cases sufficient to cover the cost of longer unprotected bonds, if that type should finally be selected for certain special conditions or to meet the preferences of individual railroads.

There is no standard length for bonds. It is known, however, that the element of length serves to aid a bond in withstanding the severe duty imposed upon it by the frequent and heavy service on main line tracks, as well as the additional stress imposed by loose and poorly supported joints in yard tracks. The estimates of cost are based upon an assumed length of 24 inches for all bonds, although in reality there would be some variation from this length to meet the requirements of the different bolt spacings and lengths of bars.

Different methods are used for attaching the bond terminals to the rail, but these have no great effect upon the total cost of installation. Bonds with tubular terminals inserted in holes drilled in the web of the rail and expanded by means of a tapered plug have been used on much important work and are made the basis of this estimate.

In determining the required number of bonds, it has been assumed that for all main line tracks both rails will be bonded and for yard and industrial tracks only one rail will be bonded. Two bonds per joint will be used in all cases, as with single bonding a break or poor contact not only increases the electrical resistance of the return circuit but it may affect the signal circuits.

The sizes of bonds to be used for the different systems and rail sections are given in table CCXC.

TABLE CCXC. SIZES OF BONDS REQUIRED FOR VARIOUS WEIGHTS OF RAIL, 2,400-VOLT D. C. SYSTEM AND 11,000-VOLT A. C. SYSTEM

Weight of Rail, Pounds per Yard	Size of Bonds in Circular Mils	
	2,400-Volt D C	11,000-Volt A. C.
100 to 85	300,000	105,500
84 to 70	250,000	105,500
Less than 70	211,600	83,690

It will be noted that bonds for the 2,400-volt direct current installation are larger than those for the 11,000-volt alternating current installation. This is due to the necessity of maintaining the voltage or resistance drop in the track return circuit within the desired limits, considering the substation spacing assumed. With the 11,000-volt alternating current system, the current in the rail is comparatively low, and as electrolysis need not be considered with such system, smaller bonds have been specified.

213.039 Cross-Bonding: The location and frequency of cross-bonds between main tracks is largely dependent upon the length of signal blocks where automatic signals are used. For purposes of these estimates, however, it has been assumed that main tracks will be cross-bonded every mile, and yard and industrial tracks at intervals of approximately 1,000 feet, with bare copper cable of the sizes shown in table CCXCI.

TABLE CCXCI. SIZES OF COPPER CABLE TO BE USED FOR CROSS-BONDING TRACKS. 2,400-VOLT D. C. SYSTEM AND 11,000-VOLT A. C. SYSTEM

Kind of Track	Size of Cable in Cir. Mils 2,400-Volt D. C.	Size of Cable in Cir. Mils 11,000-Volt A. C.
Main track	2,000,000	500,000
Yard and industrial track	750,000	211,600

213.040 Substation Connections: At each substation all tracks, the contact conductors of which are supplied from such substation, are connected electrically with the negative or grounded substation bus-bar to supply a path for the return circuit. These connections are to be of bare copper cables laid underground with terminals connected to rails in the same manner as are the bond terminals. For the 2,400-volt direct current system, 2,000,000 circular mil cables are to be used, and for the 11,000-volt alternating current system, 500,000 circular mil cables.

213.041 Unit Cost: The actual weight and length of splice bars used on main line tracks and an estimate of those for yard tracks were supplied by the railroads. Values were tabulated, and when supplemented by the average weight per foot of splice bars, as given by the manufacturers, the weight of the splice bars to be replaced was obtained. The weights of the bolts were taken from data furnished by the railroads and from manufacturers' lists. The cost of new splice bars and new bolts has been fixed at the amounts shown in the following:

	PER POUND
Cost of new splice bars	$0.015
Cost of new bolts	0.024
Scrap value of old bars and bolts	0.006
Net cost of new splice bars	0.009
Net cost of new bolts	0.018

These figures have been used in obtaining the cost of the new material for track bonding. The cost is estimated to be the same for both the 2,400-volt direct current and the 11,000-volt alternating current systems.

The cost of labor for installing the bonds for the 2,400-volt direct current system is estimated at $1.30 per joint, and for the 11,000-volt alternating current system at $1.20 per joint. These figures include the cost of the work of removing and replacing splice bars, drilling holes, installing bonds, sharpening and distributing drills, foreman's time, tools, construction office expense and superintendence, and the allowance made for the unavoidable loss of time due to interruption from traffic and inability to install bonds during even slight rain. On the basis of these figures, the costs of labor for track bonding have been estimated as shown by table CCXCII.

TABLE CCXCII. ESTIMATED COSTS OF LABOR FOR INSTALLING TRACK BONDS, PER MILE OF TRACK, 2,400-VOLT D. C. SYSTEM AND 11,000-VOLT A. C. SYSTEM
(Basis of 1912)

Kind of Track	2,400-Volt D. C.		11,000-Volt A. C.	
	30-ft. Rails	33-ft. Rails	30-ft. Rails	33-ft. Rails
1	2	3	4	5
Main track	$460	$420	$420	$385
Yard and industrial track	230	210	210	190

The cost of bonds has in all cases been taken at 40 per cent less than that quoted by the manufacturers' standard list and is as follows:

	EACH
300,000 cir. mils bond	$0.95
250,000 cir. mils bond	0.81
211,600 cir. mils bond	0.67
105,500 cir. mils bond	0.47
83,690 cir. mils bond	0.43

The estimated costs of labor and material for installing cross-bonds are shown by table CCXCIII.

TABLE CCXCIII. ESTIMATED COSTS OF LABOR AND MATERIAL FOR INSTALLING CROSS-BONDS, PER MILE OF TRACK, 2,400-VOLT D. C. SYSTEM AND 11,000-VOLT A. C. SYSTEM
(Basis of 1912)

Kind of Track	2,400-Volt D. C.	11,000-Volt A. C.
Main track	$35.00	$10.00
Yard and industrial track	50.00	15 00

The cost of substation connections per mile of main track has been estimated at $15.00 for both the 2,400-volt direct current and the 11,000-volt alternating current systems, the greater number of substations and consequently of cable connections required for the alternating current system approximately offsetting the larger cables required for the direct current system.

The several items which go to make up the unit costs of labor and material required for track bonding, cross-bonding and substation connections, exclusive of the cost of material in new splice bars, which varies so widely even with the same weight of rail that it cannot easily be tabulated, are summarized by table CCXCIV.

213.042 Estimated Costs of Return Circuit on the Basis of the Requirements of 1912, Excluding all Allowances for Contingencies and for Engineering: The estimated costs of labor and materials required for return circuit, including track and cross-bonding, new splice bars and substation connections, based upon conditions which obtained in 1912, and excluding all allowances for contingencies and for engineering, are presented by roads for the 2,400-volt direct current system in table CCXCV and for the 11,000-volt alternating current system in table CCXCVI.

The values presented in table CCXCV include the cost of bonding 0.5 mile of the double track of the Minneapolis, St. Paul & Sault Ste. Marie Railway between Altenheim and the Chicago & North Western Railway crossing. As electric operation will not be maintained over this track, it is bonded only as a negative feeder, and this cost is therefore distributed between the railroads whose tracks are benefited. For the same reason, the outside tracks of the Illinois Central Railroad between Harvey and Matteson, aggregating 16.2 single track miles, are to be bonded though not otherwise electrified. This cost is included in the estimates. Additional bonding of non-electrified track is not required for the 11,000-volt alternating current, and this item of cost is therefore not included in the values presented in table CCXCVI.

213.043 Estimated Total Cost of Return Circuit: The total cost of the return circuit for the electric operation of the Chicago railroad terminals is based on the cost of labor and materials as determined for conditions existing in the year 1912, extended in a manner normal to these estimates (chapter 212), the factors of extension in this case being as follows:

	PER CENT
1. To cover growth in mileage of railroads, December 31, 1912, to December 31, 1922	30.0
2. Contingencies	20.0
3. Engineering, design, supervision and administration	10.0
4. Interest, insurance and taxes during construction, at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

The values thus derived may be accepted as the total cost on the basis of the requirements of 1922. The estimated total cost of return circuit, including track and cross-bonding and return circuit connections to all substations, are set forth by railroads for both the 2,400-volt direct current and the 11,000-volt alternating current systems, in table CCXCVII.

PREVENTION OF INDUCTIVE EFFECTS AND ELECTROLYSIS

213.044 Inductive Effects: The methods that may be employed for the prevention of inductive effects in telephone and telegraph circuits caused by 11,000-volt single-phase alternating current

TABLE CCXCIV. SUMMARY OF ESTIMATED UNIT COSTS OF LABOR AND MATERIAL FOR RETURN CIRCUIT, 2,400-VOLT D. C. SYSTEM AND 11,000-VOLT A. C. SYSTEM *

(Basis of 1912)

Description	Cost per Mile of Track							
	2,400-Volt D. C.				11,000-Volt A. C.			
	Main Track		Yard and Industrial Track		Main Track		Yard and Industrial Track	
	30 ft. Rail	33 ft. Rail	30 ft Rail	33 ft. Rail	30 ft. Rail	33 ft. Rail	30 ft. Rail	33 ft. Rail
1	2	3	4	5	6	7	8	9
85 to 100 lb. Rail								
Cost of bonds	$670	$610	$335	$305	$330	$300	$165	$150
Cost of labor	460	420	230	210	420	385	210	190
Cross-bonding, long bonds and substation connections	50	50	50	50	25	25	15	15
Totals	1,180	1,080	615	565	775	710	390	355
70 to 84 lb. Rail								
Cost of bonds	570	520	285	260	330	300	165	150
Cost of labor	460	420	230	210	420	385	210	190
Cross-bonding, long bonds and substation connections	50	50	50	50	25	25	15	15
Totals	1,080	990	565	520	775	710	390	355
Less than 70 lb. Rail								
Cost of bonds	470	430	235	215	300	275	150	135
Cost of labor	460	420	230	210	420	385	210	190
Cross-bonding, long bonds and substation connections	50	50	50	50	25	25	15	15
Totals	$980	$900	$515	$475	$745	$685	$375	$340

* Exclusive of additional cost of new bars and bolts above the salvage value of those removed. This item of cost was estimated upon the basis of the actual material involved and not upon the basis of average cost per mile of track. The average cost per mile of track, as determined by dividing the total cost of this item for each class of track by the total mileage in that class, is as follows:

Main track..............................$229.00
Other track.............................. 87.00
Adjacent industrial track, privately owned...$ 73.00
Average for all tracks..................... 147.00

TABLE CCXCV. ESTIMATED COSTS OF LABOR AND MATERIAL FOR RETURN CIRCUIT, BY ROADS. 2,400-VOLT D. C. SYSTEM

(Basis of 1912)

Railroad	Main Track	Other Track	Adjacent Industrial Track Privately Owned	Total for All Track
1	2	3	4	5
Atchison, Topeka & Santa Fe Railway	$ 36,524	$ 32,682	$ 3,511	$ 72,717
Baltimore & Ohio Railroad	41,438	16,785	643	58,866
Baltimore & Ohio Chicago Terminal Railroad	77,748	24,896	5,000	107,644
Calumet, Hammond & Southeastern Railroad	0	3,775	0	3,775
Chesapeake & Ohio Railway of Indiana	0	116	0	116
Chicago & Alton Railroad	23,760	21,630	1,555	46,945
Chicago & Calumet River Railroad	0	2,021	11,305	13,326
Chicago & Eastern Illinois Railroad	2,933	11,261	690	14,884
Chicago & Erie Railroad	7,097	12,991	170	20,258
Chicago & North Western Railway	351,412	174,604	6,103	532,119
Chicago & Western Indiana Railroad and the Belt Railway of Chicago	182,902	103,442	8,814	295,158
Chicago, Burlington & Quincy Railroad	102,041	50,925	10,317	163,283
Chicago Great Western Railroad	937	11,757	24	12,718
Chicago, Indiana & Southern Railroad	11,891	1,390	0	13,281
Chicago, Indianapolis & Louisville Railway	5,088	1,019	0	6 107
Chicago Junction Railway	51,405	75,851	22,340	149,596
Chicago, Milwaukee & St. Paul Railway	134,763	95,790	11,248	241,801
Chicago River & Indiana Railroad	6,364	562	2,297	9,223
Chicago, Rock Island & Pacific Railway	94,305	38,332	......	132,637
Chicago Short Line Railway	0	377	3,013	3 390
Chicago Union Transfer Railway	7,032	1,515	96	8,643
Chicago, West Pullman & Southern Railroad	0	2,066	10,038	12,104
Elgin, Joliet & Eastern Railway	8,274	68,986	1,588	78 848
Grand Trunk Western Railway	27,318	23,552	3,559	54,429
Illinois Central Railroad	249,038	97,225	2,403	348,666
Illinois Northern Railway	5,381	4,395	5,447	15,223
Indiana Harbor Belt Railroad	28,895	390	0	29,285
Lake Shore & Michigan Southern Railway	128,630	38,927	582	168,139
Michigan Central Railroad	32,442	35,662	1,086	69,190
Minneapolis, St. Paul & Sault Ste. Marie Railway *	......	......	......	......
New York, Chicago & St. Louis Railroad	34,834	16,009	0	50,843
Pere Marquette Railroad	0	5,737	0	5,737
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	90,739	47,708	3,063	141,510
Pittsburgh, Fort Wayne & Chicago Railway	168,161	56,924	7,872	232,957
Pullman Railroad	7,627	4,922	17,167	29,716
Wabash Railroad	27,636	30,061	291	57,988
Totals	$1,946,615	$1,114,285	140,222	$3,201,122

* Owns no track to be electrified.

TABLE CCXCVI. ESTIMATED COSTS OF LABOR AND MATERIAL FOR RETURN CIRCUIT, BY ROADS, 11,000-VOLT A. C. SYSTEM
(Basis of 1912)

Railroad	Main Track	Other Track	Adjacent Industrial Track Privately Owned	Total for All Track
1	2	3	4	5
Atchison, Topeka & Santa Fe Railway	$ 25,823	$ 24,023	$ 2,664	$ 52,510
Baltimore & Ohio Railroad	29,983	11,643	496	42,122
Baltimore & Ohio Chicago Terminal Railroad	58,463	18,481	3,806	80,750
Calumet, Hammond & Southeastern Railroad	0	2.742	0	2,742
Chesapeake & Ohio Railway of Indiana	0	84	0	84
Chicago & Alton Railroad	17,755	15,832	1,138	34,725
Chicago & Calumet River Railroad	0	1,468	8,179	9,647
Chicago & Eastern Illinois Railroad	2,082	8,521	525	11,128
Chicago & Erie Railroad	5,447	9,371	130	14,948
Chicago & North Western Railway	254,068	129,286	4,628	387,982
Chicago & Western Indiana Railroad and the Belt Railway of Chicago	138,582	77,069	6,639	222,290
Chicago, Burlington & Quincy Railroad	73,362	39,538	7,859	120,759
Chicago Great Western Railroad	662	8,202	18	8,882
Chicago, Indiana & Southern Railroad	8,498	1,055	0	9,553
Chicago, Indianapolis & Louisville Railway	3,616	758	0	4,374
Chicago Junction Railway	38,920	55,102	16,232	110,254
Chicago, Milwaukee & St Paul Railway	96,988	70,214	8,498	175,700
Chicago River & Indiana Railroad	4,812	409	1,675	6,896
Chicago, Rock Island & Pacific Railway	69,151	28,228	0	97,379
Chicago Short Line Railway	0	265	2,118	2,383
Chicago Union Transfer Railway	5,377	1,114	70	6,561
Chicago, West Pullman & Southern Railroad	0	1,475	7,295	8,770
Elgin, Joliet & Eastern Railway	5,975	49,717	1,208	56,900
Grand Trunk Western Railway	20,719	17,541	2,709	40,969
Illinois Central Railroad	169,135	73,310	1,818	244,263
Illinois Northern Railway	4,073	3,307	4,147	11,527
Indiana Harbor Belt Railroad	20,470	285	0	20,755
Lake Shore & Michigan Southern Railway	97,501	29,215	443	127,159
Michigan Central Railroad	23,974	27,046	826	51,846
Minneapolis, St. Paul & Sault Ste. Marie Railway*	......	......	......	......
New York, Chicago & St. Louis Railroad	26,254	12,171	0	38,425
Pere Marquette Railroad	0	4,282	0	4,282
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	65,600	34,444	2,314	102,367
Pittsburgh, Fort Wayne & Chicago Railway	122,006	40,997	6,008	169,011
Pullman Railroad	5,989	3,715	12,966	22,670
Wabash Railroad	21,116	22.783	221	44,120
Totals	$1.416,410	$823,693	$104,630	$2,344,733

* Owns no track to be electrified.

railroad circuits have been described (chapter 207). After a study of conditions in the Chicago terminals, the conclusion has been reached (chapter 208) that induction can be prevented by providing rather liberal bonding of track rails, by careful arrangement of feeding points for the railroad circuits and by installing booster transformers in the railroad circuits. Neutralizing apparatus will not be required in the telephone and telegraph circuits to compensate or overcome induction, as the methods to be employed will eliminate the inductive effect. It will not be necessary for telephone and telegraph lines to be cabled or moved from the vicinity of the railroad circuits to any extent greater than that required to prevent physical interference, as described in section 213.078. Some 200 miles of wire lines parallel to railroad tracks, 75 per cent of this mileage being telephone and telegraph lines, will need to be changed to eliminate the possibility of physical interference. These changes will be made either by moving the open wire lines to a greater distance from the railroad tracks, or by cabling the wires and placing them on the overhead supporting structures of the contact system or, in some instances, underground. They will, in extreme cases when unusual disturbances occur, have a beneficial effect upon inductive interference, but they are not resorted to as an expedient to this end.

The track bonding to be provided for the return circuit of the 11,000-volt alternating current system (section 213.038) is more liberal than would be installed were inductive effects not a factor in the use of this system. Double bonds at each rail joint will help to insure against broken bonds and possible high resistance joints; also the bonding of both rails of the main track will provide a low resistance return circuit, thus aiding in keeping the return current in the rail.

Frequent feeding points are to be provided by locating substations at intervals of from five to eight miles. In all cases there will be a substation at or near the ends of the electrified railroads and at the more important junction points in the

TABLE CCXCVII. ESTIMATED TOTAL COST OF RETURN CIRCUIT, BY ROADS, 2,400-VOLT D. C. SYSTEM AND 11,000-VOLT A. C. SYSTEM

(Dec. 31, 1922)

Railroad	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3
Atchison, Topeka & Santa Fe Ry	$ 137,884	$ 99,569
Baltimore & Ohio R. R.	111,620	79,871
Baltimore & Ohio Chicago Terminal R. R.	204,111	153,117
Calumet, Hammond & Southeastern R. R.	7,158	5,200
Chesapeake & Ohio Ry. of Indiana	220	159
Chicago & Alton R. R.	89,016	65,844
Chicago & Calumet River R. R.	25,269	18,292
Chicago & Eastern Illinois R. R.	28,223	21,100
Chicago & Erie R. R.	38,412	28,343
Chicago & North Western Ry	1,008,994	735,684
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	559,673	421,501
Chicago, Burlington & Quincy R. R.	309,614	228,980
Chicago Great Western R. R.	24,116	16,842
Chicago, Indiana & Southern R. R.	25,183	18,114
Chicago, Indianapolis & Louisville Ry	11,580	8,293
Chicago Junction Ry	283,661	209,062
Chicago, Milwaukee & St. Paul Ry	458,498	333,159
Chicago River & Indiana R. R.	17,489	13,076
Chicago, Rock Island & Pacific Ry	251,504	184,649
Chicago Short Line Ry	6,428	4,519
Chicago Union Transfer Ry	16,388	12,441
Chicago, West Pullman & Southern R. R.	22,951	16,629
Elgin, Joliet & Eastern Ry	149,509	107,892
Grand Trunk Western Ry	103,208	77,685
Illinois Central R. R.	661,134	463,166
Illinois Northern Ry	28,866	21,857
Indiana Harbor Belt R. R.	55,529	39,355
Lake Shore & Michigan Southern Ry	318,818	241,117
Michigan Central R. R.	131,197	98,310
Minneapolis, St. Paul & Sault Ste. Marie Ry.*	....	....
New York, Chicago & St. Louis R. R.	96,408	72,860
Pere Marquette R. R.	10,879	8,120
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	268,329	194,105
Pittsburgh, Fort Wayne & Chicago Ry	441,728	320,475
Pullman R. R.	56,347	42,987
Wabash R. R.	109,955	83,660
Totals	$6,069,899	$4,446,033

* Owns no track to be electrified.

electrified district. With this arrangement the tracks will be divided into sections fed by substations at each end. The current drawn by trains in any one section will be confined to that section and as a consequence the inductive disturbance will be largely balanced out.

The booster transformers for the railroad circuits are to be series transformers of approximately 1 : 1 ratio, one coil being in series with the overhead contact wire and the other coil being in series with the track rail and connected into the middle point of induction bonds where signals are used, or at each side of insulated joints installed in the rail where there are no signals. These transformers are to be located about one mile apart on main lines having heavy traffic and one and one-half miles apart on main lines having light traffic. Locations are to be so chosen that transformers will be provided near entrances to yards to handle the circuits in the yards in addition to the main tracks. At many locations the transformers will serve jointly the contiguous tracks of more than one railroad.

The cost of track bonding and the total cost of substations could probably be reduced if inductive interferences in neighboring telephone and telegraph lines were not the result of grounded alternating current circuits. However, the benefits to be obtained by having double bonding, low resistance return circuits and numerous substations, are also great in other respects. No effort has been made to determine the increment necessary in these items to overcome inductive effects. Since, however, the booster transformers are an additional expense required solely to eliminate induction incident to the single-phase alternating current system, their cost is here given as the cost of preventing inductive effects.

213.045 Electrolysis: The provisions which may be made to prevent or to limit damage to water and gas pipes and other sub-surface metallic structures, resulting from electrolysis caused by the return currents of the 2,400-volt direct current system, have been enumerated (chapter 207). The Committee's conclusions regarding the means to be employed to accomplish this are stated in chapter 208.

The plans provide for liberal bonding (section 213.038) and for substations so located that the sustained average difference of potential between points on the return circuits will be within the limits allowed. It is probable that, were electrolysis not a factor, the track bonding could be less liberal, the substations in some cases could be spaced at greater intervals and the equipment for substations could be less elaborate. The difference between the cost of substations and equipment entirely adequate for operating purposes and that of the lay-out which has served as a basis for these estimates might reasonably be considered as the cost of guarding against electrolysis. Since, however, all of the provisions made to prevent electrolysis tend to increase the efficiency of the system by reducing losses in the return circuit, and to improve operation by providing better voltage regulation, the segregated cost of these provisions is not presented nor has it been determined.

213.046 Estimated Costs of Induction Prevention on the Basis of the Requirements of 1912, Excluding all Allowances for Contingencies and

for Engineering: The estimated costs of the booster transformers required to prevent induction have been estimated on the basis of the lay-out already described. The estimates of cost, based on conditions which obtained in 1912 and excluding all allowances for contingencies and for engineering, for the booster transformer installations required for the 11,000-volt alternating current system are presented in table CCXCVIII.

TABLE CCXCVIII. ESTIMATED COSTS OF BOOSTER TRANSFORMER INSTALLATIONS FOR THE PREVENTION OF INDUCTION, 11,000-VOLT A. C. SYSTEM

(Basis of 1912)

No. of Booster Transformer Installations	No. of Tracks at Each Installation	Cost per Installation	Total Cost
1	2	3	4
22	1	$ 675	$ 14,850
151	2	1,000	151,000
37	3	1,325	49,025
54	4	2,000	108,000
4	5	2,325	9,300
28	6	2,650	74,200
17	8	3,650	62,050
5	9	3,975	19,875
5	10	4,550	22,750
2	14	7,300	14.600
325			$525,650

213.047 Estimated Total Cost of Induction Prevention: The total cost of the booster transformers for preventing induction under electric operation of the Chicago railroad terminals is based on the cost of labor and materials as determined for 1912, extended in a manner normal to these estimates (chapter 212), the factors of extension in this case being as follows:

	PER CENT
1. To cover growth in mileage of railroads, December 31, 1912, to December 31, 1922	30.0
2. Contingencies	20.0
3. Engineering, design, supervision and administration	10.0
4. Interest, insurance and taxes during construction, at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

The value thus derived may be accepted as the total cost on the basis of requirements for 1922. The cost has been divided among the several railroads to be served on the basis of the total mileage of tracks to be electrified.

The total cost, by railroads, of preventing induction by the installation of booster transformers, is set forth for the 11,000-volt alternating current system in table CCXCIX.

TABLE CCXCIX. ESTIMATED TOTAL COST OF INDUCTION PREVENTION, BY ROADS, 11,000-VOLT A. C. SYSTEM

(Dec. 31, 1922)

Railroad	Total Cost
Atchison, Topeka & Santa Fe Ry	$ 25,488
Baltimore & Ohio R. R	17,236
Baltimore & Ohio Chicago Terminal R. R	33,158
Calumet, Hammond & Southeastern R. R	1,710
Chesapeake & Ohio Ry. of Indiana	52
Chicago & Alton R. R	17,075
Chicago & Calumet River R. R	6,092
Chicago & Eastern Illinois R. R	6,566
Chicago & Erie R. R	9,923
Chicago & North Western Ry	154,234
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	92,430
Chicago, Burlington & Quincy R. R	53,658
Chicago Great Western R. R	5,967
Chicago, Indiana & Southern R. R	3,413
Chicago, Indianapolis & Louisville Ry	1,635
Chicago Junction Ry	57,521
Chicago, Milwaukee & St. Paul Ry	75,600
Chicago River & Indiana R. R	3,010
Chicago, Rock Island & Pacific Ry	40,250
Chicago Short Line Ry	1,536
Chicago Union Transfer Ry	2,350
Chicago, West Pullman & Southern R. R	5,182
Elgin, Joliet & Eastern Ry	32,819
Grand Trunk Western Ry	18,653
Illinois Central R. R	97,673
Illinois Northern Ry	6,054
Indiana Harbor Belt R. R	6,774
Lake Shore & Michigan Southern Ry	47,370
Michigan Central R. R	19,772
Minneapolis, St. Paul & Sault Ste. Marie Ry.*	......
New York, Chicago & St. Louis R. R	16,826
Pere Marquette R. R	2,812
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	39,456
Pittsburgh, Fort Wayne & Chicago Ry	60,500
Pullman Railroad	13,216
Wabash Railroad	20,716
Total	$996,727

* Owns no track to be electrified.

TELEPHONE SYSTEM

213.048 General Considerations: With any system of electric operation, it is essential that all elements of the electric installation be in close communication with one another. To this end a more complete telephone system is required than is necessary with steam operation. As a basis of estimates of cost, it has been assumed that there will be a central telephone exchange at the power station under the direction of a chief power operator. From this exchange there will be a separate line to each substation and switching station and to the general or dispatcher's office of each electrified railroad. Telephones will also be required at each of the locomotive terminals. It has been assumed that all of the lines and equipment for this service will be installed and maintained by the local telephone company on a rental basis and that there will be no cost to the railroad for their installation.

Radiating from certain important substations, there are to be telephone patrol lines which will be installed and owned by the railroad companies. These patrol lines will provide for the prompt transmission of reports concerning defects or troubles of any kind found by the men who will patrol the electric lines. Their cost is the only item for telephone system that enters into the installation cost of electrification.

213.049 Telephone Patrol Lines: The wires of the telephone patrol line are to be carried on the existing telephone or telegraph poles along the rights-of-way. Instruments to be rented from the telephone company are to be located in weather-proof boxes or shelters protected with standard switch locks, so that all authorized employes may have access to them in case of emergency. The operator at the substation with which any section of the patrol line may connect will answer calls from patrolmen and when necessary make connection with the power station operator.

It is assumed that each road will have control over the operation of its own tracks, and a patrol line with two stations per mile is to be provided along all electrified right-of-way. The spacing of the instruments is to be varied slightly where necessary to permit of locating at or near signal bridges, passenger stations, interlocking towers or other service buildings, at points where these may exist or where they may be established.

The smaller roads which consist principally of yard and industrial tracks, and which may be said to have no route mileage, will presumably be served by the telephone system along the right-of-way of an adjacent road, and no allowance is included in these estimates for telephone patrol line for such small roads.

213.050 Unit Costs of Telephone Patrol Line: The estimated unit costs of labor and materials for the telephone patrol line vary from \$250 to \$350 per circuit mile, depending upon the extent to which space on the present poles and cross-arms may be used for the additional wires. Where this space is not available, new arms or brackets and in some cases even new poles may be required. The estimates which follow are based upon an average cost of \$300 per route mile.

213.051 Estimated Costs of Telephone System on the Basis of the Requirements of 1912, Excluding all Allowances for Contingencies and for Engineering: From the estimated unit costs of the telephone patrol presented in the preceding section and the route mileage to be electrified as given for each road in chapter 209, the costs of the telephone system have been estimated. These estimates of cost, excluding all allowances for contingencies and for engineering, are set forth in table CCC.

TABLE CCC. ESTIMATED COSTS OF LABOR AND MATERIAL FOR TELEPHONE SYSTEM, BY ROADS
(Basis of 1912)

Railroad	Total Cost
Atchison, Topeka & Santa Fe Railway	\$ 3,630
Baltimore & Ohio Railroad	4,890
Baltimore & Ohio Chicago Terminal Railroad	10,650
Calumet, Hammond & Southeastern Railroad	0
Chesapeake & Ohio Railway of Indiana	0
Chicago & Alton Railroad	3,000
Chicago & Calumet River Railroad	0
Chicago & Eastern Illinois Railroad	390
Chicago & Erie Railroad	810
Chicago & North Western Railway	27,510
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	14,580
Chicago, Burlington & Quincy Railroad	5,970
Chicago Great Western Railroad	0
Chicago, Indiana & Southern Railroad	1,440
Chicago, Indianapolis & Louisville Railway	1,050
Chicago Junction Railway	3,540
Chicago, Milwaukee & St. Paul Railway	13,860
Chicago River & Indiana Railroad	330
Chicago, Rock Island & Pacific Railway	8,970
Chicago Short Line Railway	0
Chicago Union Transfer Railway	1,050
Chicago, West Pullman & Southern Railroad	0
Elgin, Joliet & Eastern Railway	840
Grand Trunk Western Railway	3,120
Illinois Central Railroad	14,160
Illinois Northern Railway	1,050
Indiana Harbor Belt Railroad	2,970
Lake Shore & Michigan Southern Railway	9,030
Michigan Central Railroad	3,420
Minneapolis, St. Paul & Sault Ste. Marie Railway*	......
New York, Chicago & St. Louis Railroad	4,110
Pere Marquette Railroad	0
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	8,670
Pittsburgh, Fort Wayne & Chicago Railway	15,750
Pullman Railroad	1,950
Wabash Railroad	2,820
Total	\$169,560

* Owns no track to be electrified.

213.052 Estimated Total Cost of Telephone System: In extending costs to cover growth subsequent to the year 1912, it has been assumed that the mileage of railroad routes within the area to be electrified will not materially increase, and that the cost of the telephone system, which is based upon route mileage, will therefore not be greatly affected by growth. But the trackage and the traffic will increase and the growth of these may be expected to bring about some elaboration of the telephone patrol system. It has therefore been assumed, for the purpose of these estimates, that a flat allowance of 10 per cent of the cost as estimated for the year 1912 will be sufficient to provide for the increase in facilities affecting the extent of the telephone system during the period between 1912 and 1922. Allowances for contingencies and other factors normal to all estimates (chapter 212) are also made, the factors of extension in this case being as follows:

	PER CENT
1. To cover growth in traffic and trackage of railroads, December 31, 1912, to December 31, 1922	10.0
2. Contingencies	20.0

3. Engineering, design, supervision and administration	10.0
4. Interest, insurance and taxes during construction, at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

The estimated total cost of the telephone system on the basis outlined is presented for each road in table CCCI.

TABLE CCCI. ESTIMATED TOTAL COST OF TELEPHONE SYSTEM, BY ROADS
(Dec. 31, 1922)

Railroad	Total Cost
Atchison Topeka & Santa Fe Railway	$ 5,824
Baltimore & Ohio Railroad	7,846
Baltimore & Ohio Chicago Terminal Railroad	17,087
Calumet, Hammond & Southeastern Railroad	0
Chesapeake & Ohio Railway of Indiana	0
Chicago & Alton Railroad	4,813
Chicago & Calumet River Railroad	0
Chicago & Eastern Illinois Railroad	626
Chicago & Erie Railroad	1,300
Chicago & North Western Railway	44,138
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	23,393
Chicago, Burlington & Quincy Railroad	9,579
Chicago Great Western Railroad	0
Chicago, Indiana & Southern Railroad	2,310
Chicago, Indianapolis & Louisville Railway	1,685
Chicago Junction Railway	5,680
Chicago, Milwaukee & St. Paul Railway	22,238
Chicago River & Indiana Railroad	529
Chicago, Rock Island & Pacific Railway	14,392
Chicago Short Line Railway	0
Chicago Union Transfer Railway	1,685
Chicago, West Pullman & Southern Railroad	0
Elgin, Joliet & Eastern Railway	1,348
Grand Trunk Western Railway	5,006
Illinois Central Railroad	22,719
Illinois Northern Railway	1,685
Indiana Harbor Belt Railroad	4,765
Lake Shore & Michigan Southern Railway	14,488
Michigan Central Railroad	5,487
Minneapolis, St. Paul & Sault Ste. Marie Ry*	......
New York, Chicago & St. Louis Railroad	6,594
Pere Marquette Railroad	0
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	13,911
Pittsburgh, Fort Wayne & Chicago Railway	25,270
Pullman Railroad	3,129
Wabash Railroad	4,525
Total	$272,052

* Owns no track to be electrified.

ELECTRIC LOCOMOTIVES, MULTIPLE-UNIT EQUIPMENT, WORK AND INSPECTION EQUIPMENT

213.053 General Considerations: There is as yet no standardized type of electric locomotive. Every important electric railroad performing heavy service is using locomotives designed and constructed for its individual work. These designs may differ in the grouping of wheels, in the mounting of motors, in the mechanism connecting armature with wheels and in adaptation to the requirements of the electric system employed. These differences are generally unimportant as factors in the development of this report, but in order that an estimate of cost might be made, it has been necessary to fix a design and to specify certain mechanical and electrical characteristics. It is to be understood, however, that the designs thus specified are not necessarily regarded as being preferable to all others. They have been selected largely because definite information is available as to the cost and performance of units built from them, and because it is probable that other designs which might be used would not differ materially in cost from those selected. In estimating the energy requirements, the 600-volt direct current equipment was made the basis of all initial determinations. Energy requirements and operating results of the 2,400-volt direct current and the 11,000-volt alternating current equipment have been derived from those initially obtained for the 600-volt direct current equipment.

213.054 The Service: Preliminary to a determination of the characteristics of the electric locomotives to be used on the Chicago terminals, the work now being done by steam locomotives has been carefully studied. The performance of existing steam locomotives has been set forth in reports made by the railroads and in results of tests conducted under service conditions in connection with the Committee's investigation. The facts thus obtained constitute a definition of the work to be done in the operation of the Chicago terminals.

In all of the Committee's work the different locomotive services have been classified as follows:

1. Yard.
2. Road freight.
3. Freight transfer.
4. Passenger transfer
5. Through passenger.
6. Suburban passenger.

A review of returns has shown that the passenger transfer service, defined as "the movement of passenger cars, loaded and empty, between railroads or between yards of the same railroad that are not contiguous," constitutes a very small part of the work in the terminals. As measured in ton-miles, it is about one per cent of the total. It is now performed entirely by yard locomotives, and any type of electric locomotive suitable for yard service may be employed for this work. Similarly, that part of the suburban passenger service which cannot best be handled by multiple-unit trains is sufficiently similar to the through passenger service to permit of its being handled by a type of locomotive employed in that service. There remain, then, yard, road freight, freight transfer and through passenger services, for which suitable electric locomotives are to be provided.

On first consideration it would seem that the type of electric locomotive to be provided for handling any class of service should be determined on the basis of the characteristics of the steam equipment now performing that service. But it must be borne in mind that many roads are involved, that a study of the practices of different roads discloses many differences, and that the weight and power of many locomotives in service are far below the maximum requirements of the present day. Consequently, the power characteristics of the steam locomotives which now perform the greater part of any service would not be perpetuated if all the present equipment were to be renewed. Again, the well-known fundamental differences between steam and electric locomotives make direct comparisons difficult. With full consideration of these aspects of the problem, the traffic and train movements of the Chicago terminals for 1912 have been analyzed, the characteristics of the locomotives employed have been tabulated and studied and, so far as practicable, the information thus obtained has been utilized.

213.055 Electric Locomotive for Yard Service: From the reports of ten roads, representing 63 per cent of the locomotive-hours of yard service performed within the Area of Investigation, it was found that 75 per cent of the steam locomotives engaged in this service carry between 100,000 and 175,000 pounds on drivers, and that 12 per cent carry more than 175,000 pounds on drivers, the maximum being 225,000 pounds. From 103 tests made in 66 yards of 13 railroads, covering over 800 locomotive-hours of service, the average weight on drivers of the locomotives tested was found to be 138,000 pounds.

The average run in this service, as determined from the tests made in yards under service conditions, was found to be as follows:

Average length of run	628 feet
Average time of run	1 min. 19½ sec.
Average time of stop	53 sec.
Average speed while in motion	5.4 miles per hour
Average speed, including stops	3.24 miles per hour
Average trailing load	306 tons

The modern steam switching locomotive is of greater weight than the average of all those now in service. As compared with these steam locomotives an electric locomotive may, through the ease with which its wheel arrangement can be articulated, have greater total weight on drivers without increasing the load per wheel or the length of the rigid wheel base. As a consequence, an electric locomotive may have greater maximum tractive effort without exceeding or even equaling the total weight of the present steam locomotive and tender. From such consideration as has been given the matter, the weight of the electric locomotive for yard service has been taken for all systems as 160,000 pounds, all on drivers. The estimates are based on a locomotive with two 4-wheel trucks, and on account of the low speeds required in this service, the motors are assumed to be geared to the axles. This locomotive is to be equipped with four 120-horse-power motors and will handle the average trailing load, as defined above, over the average length of run at 5.5 miles per hour by operating in series-parallel or at 7.2 miles per hour by operating in parallel. At the normal one-hour rating, the capacity of the locomotive will be 480 horse-power, that is, the locomotive can develop this power for one hour without stopping, with a temperature rise in the motors not exceeding 75 degrees centigrade. At this rating, it will develop 21,500 pounds tractive effort at 8.6 miles per hour and 11,500 pounds tractive effort continuously at 10.3 miles per hour. Its power capacity for short intervals of time will greatly exceed these limits, and momentarily it will develop a tractive effort of 50,000 pounds, or sufficient to slip the wheels at 31.2 per cent adhesion without exceeding the commutating limit.

213.056 Electric Locomotive for Road Freight Service: The speeds required in this service, as observed from 22 tests, averaged about 15 miles per hour and the maximum was a little more than 40 miles per hour. The average results of the 22 tests made in this service compared with the average throughout the year, as taken from the reports of all roads, are shown in the following:

	TESTS	REPORTS
Locomotive-hours	21.97	22,500
Average trailing load, tons	1,320	988
Average speed while in motion, miles per hour	14.9	.....
Average speed including stops, miles per hour	11.7	9.4
Average length of run, miles	2.8	.....

The electric locomotive for road freight service selected as a basis for estimates is similar in wheel and truck arrangement to the yard locomotive except that it has eight motors, two of which are geared to each of the four axles. The weight has been taken as 200,000 pounds for the 600-volt and 2,400-volt direct current systems and as 230,000 pounds for the 11,000-volt alternating current system. Economical operation may be maintained over a wide range of speeds by having the control system provide for three motor groupings, *i. e.*, series, series-parallel and parallel. The motors are each to be of 250-horse-power capacity on the one-hour rating. Eight motors will develop a tractive effort of 80,000 pounds, or sufficient to slip the wheels at 40 per cent adhesion without exceeding the commutating limit, and will develop 19,200 pounds tractive effort at 22.5 miles per hour continuously, and 40,000 pounds at 18.5 miles per hour for one hour.

The locomotive is capable, if operated in parallel, of handling the average trailing load at an average speed while in motion of about 22 miles per hour, which, as shown by the tests, is about 50 per cent greater than the average speed of the present steam locomotive. Operation in series-parallel will reduce this when desired and will, of course, reduce the energy consumption.

213.057 Electric Locomotive for Freight Transfer Service: The character of the freight transfer service, as developed by 58 tests and by the reports of all roads for 1912, is shown in the following:

	TESTS	REPORTS
Locomotive-hours	148.21	62,000
Average trailing load, tons	1,311	811
Average speed while in motion, miles per hour	8.1	.....
Average speed including stops, miles per hour	5.3	5.7
Average length of run, miles	0.376	.....

As in the case of road freight service, the results show that the service selected for test was heavier than the average of the same service for all roads throughout the year. The average trailing load for freight transfer trains tested was more than 60 per cent greater than the average of all trains as reported. Much of the present freight transfer service is handled by locomotives which are essentially yard locomotives, and in determining the electric energy required it has been assumed that the electric locomotives provided for yard service will perform much of the transfer service. That portion of the service which cannot well be performed by yard locomotives will be operated by the type of locomotive specified for road freight service. This road freight locomotive will handle the transfer service as herein set forth with motors in series-parallel at about 10 miles per hour, which speed is to be compared with 8.1 miles per hour now being maintained in the steam operated service.

For the purpose of these estimates it is assumed, therefore, that no locomotive is to be especially designed for freight transfer work.

213.058 Electric Locomotive for Passenger Service: The maximum trailing weight of passenger trains to be handled is about 900 tons. Most of the lighter trains, and those making very frequent stops, are to be operated with multiple-unit motor cars, leaving the through passenger trains and suburban trains which go to points beyond the limits of electrification to be handled by electric passenger locomotives. Although there is a very considerable difference in the weights of trains, only one type of locomotive has been selected for this service, the freight locomotive being available for trains making frequent stops. The locomotive for passenger service selected as a basis of estimates is of the double or articulated type, each half being similar in wheel arrangement and frame to the "American" type or eight-wheel steam locomotive. Motors aggregating 2,000 horse-power are mounted in the cabs above the frame. Cranks and connecting rods drive jack shafts which in turn connect through coupling rods to the driving wheels. For both of the direct current systems, the total weight is assumed to be 310,000 pounds and for the alternating current system, 320,000 pounds. The weight on driving wheels in both cases is taken as 63 per cent of the total. At the normal or one-hour rating of the motors, the locomotive will develop 24,000 pounds tractive effort at 31.5 miles per hour. It will attain a speed of 60 miles per hour with a 550-ton train on level tangent track and, without exceeding the momentary capacity of the motors, will slip the wheels at more than 30 per cent adhesion.

213.059 Multiple-Unit Cars for Suburban Passenger Service: The cars at present used in that part of the suburban passenger service which is to be operated by multiple-unit cars vary in length of body from 39 to 64 feet, in weight from 35,000 to 88,700 pounds, and in seating capacity from 40 to 100 passengers. In selecting a type of car on which to base estimates of cost for this service, no attempt has been made to duplicate these varying characteristics, the assumption being that if new equipment were to be provided it would be of uniform character for any one road, and also that there is not sufficient variation in the character of the service on the different roads to require differences in equipment. Only one design of motor car has therefore been considered. Following the practice of roads elsewhere which have operated multiple-unit service, and the evident tendency of steam roads in providing new passenger equipment, the use of steel cars has been assumed as a basis of estimates.

The weights, dimensions and seating capacities of motor cars now used in multiple-unit service by four electrified steam railroads are shown by table CCCII.

TABLE CCCII. CHARACTERISTICS OF MULTIPLE-UNIT MOTOR CARS IN USE ON EXISTING STEAM RAILROAD ELECTRIFICATIONS

Railroad	Total Weight without Passengers, lb.	Length over Body	Length over Buffers	Width over Eaves	Number Seated Passengers
1	2	3	4	5	6
New York Central & Hudson River Railroad	102,600	50 ft.	60 ft.	9 ft. 10½ in.	64
Pennsylvania Railroad Long Island Railroad	110.400	54 ft. 6¼ in.	64 ft. 5¾ in.	10 ft. 5⅞ in.	72
Southern Pacific Railroad	109,400	58 ft. 6½ in.	72 ft. 10½ in.	10 ft. 5⅞ in.	116

As a basis for estimates of cost and energy required, a motor car has been selected which, when fully equipped and with average seated load, weighs 110,000 pounds for the 600-volt direct current system, 126,000 pounds for the 2,400-volt direct current system and 117,000 pounds for the 11,000-volt alternating current system. It is approximately 54 feet long over the body and 64 feet long over all, and has seating capacity for 70 passengers. It will be noted that, as regards length and seating capacity, this is close to the average of the largest and smallest cars in the present steam service, and as regards length it corresponds also to the average of the three examples of motor cars mentioned in table CCCII.

Each motor car is equipped with motors having a total capacity, with forced ventilation, of 500 horse-power at the one-hour rating. For the 600-volt direct current and 11,000-volt alternating current systems there are but two motors, both mounted on the same truck. For the 2,400-volt direct current system there are four motors, two mounted on each truck.

The combination passenger and baggage cars selected have the same dimensions, motor equipment and weight as the motor coaches just described and seat 50 passengers. The trailer cars have the same dimensions as the motor cars, seat 70 passengers and weigh, with average seated load, 88,000 pounds. They are to be equipped with master-controllers at both ends, so that they can be used to operate the train when at the head end. The 600-volt trailers are to have contact shoes and power bus line, so that the train may operate satisfactorily over the maximum span at third rail gaps.

The assumed make-up of trains provides a seating capacity nearly 10 per cent greater than that of the present trains. The relative number of motor and trailer cars per train has been fixed, for these estimates, as shown by table CCCIII.

TABLE CCCIII. MAKE-UP OF MULTIPLE-UNIT TRAINS

Motor Cars	Trailer Cars	Total Cars in Train
1	2	3
2	0	2
2	1	3
3	1	4
3	2	5
4	2	6
4	3	7
5	3	8

Multiple-unit trains made up as indicated will permit an increase of speed of from 5 to 10 per cent on short runs and the duplication of present speeds on long runs. It is estimated that, on the average, multiple-unit equipment will provide speeds about 5 per cent higher than those now common under steam operation. The rate of acceleration of a five-car train will be about one mile per hour per second and its maximum speed on tangent track about 55 miles per hour.

213.060 Basis for Determining the Number of Units of Equipment Required: The number of electric locomotives and multiple-unit motor and trailer cars which will be required under the proposed electric operation of the Chicago terminals is a function of the extent of the trackage to be electrified and of the density of traffic to be handled. The extent of the plan of electrification which underlies the Committee's estimates of cost is set forth in detail in chapter 209. The considerations which controlled the development of the plan, and the practices involved in the operation of the entire terminal and in that of individual roads, are discussed in that chapter in connection with statistical facts relating to the extent of trackage and the volume of traffic. A summary of this statistical information is presented in the following:

	MILES
Main track	1,475.59
Other track	1,733.83
Adjacent industrial track, privately owned	229.72
Total electrically equipped track	3,439.14

The volume of traffic handled over this trackage, as determined for the year 1912, is set forth in chapter 202. From this record such summarized statements as are needed for the present study have been taken.

Classification of Services

The service to be conducted over the proposed electrified trackage of the Chicago terminals is, for the present purpose, divided into four classes:

1. Locomotive passenger.
2. Multiple-unit passenger.
3. Road freight.
4. Yard and transfer.

Under electric operation locomotive passenger service will ordinarily be performed by electric passenger locomotives, general specifications for which are set forth in section 213.058.

Multiple-unit passenger service will be performed by multiple-unit motor and trailer cars, general specifications for which are set forth in section 213.059.

Road freight service will ordinarily be performed by electric road freight locomotives, general specifications for which are set forth in section 213.056.

Yard and transfer service will ordinarily be performed by electric yard locomotives, general specifications for which are set forth in section 213.055. This service comprises the three services hereinbefore designated as yard, freight transfer and passenger transfer.

Density of Traffic for the Average Day in Each Class of Service

The number of train-miles made daily in each of the different classes of service over the trackage to be electrified is as follows:

	TRAIN-MILES
Locomotive passenger	12,460
Multiple-unit passenger	11,328
Road freight	5,369
Yard and transfer (locomotive-miles)	34,673
Total	63,830

The number of trains scheduled in passenger service, based on railroad time-tables of October, 1912, is as follows:

	AVERAGE NO. PER DAY
Locomotive passenger	704
Multiple-unit passenger	661
Total	1,365

The number of ton-miles and of locomotive-hours of service performed in road freight service is as follows:

	FOR AVERAGE DAY
Trailing ton-miles	5,668,326
Locomotive-hours of service	548

The number of locomotive-hours performed in yard and transfer service is as follows:

	FOR AVERAGE DAY
Yard	7,625
Freight transfer	1,617
Passenger transfer	140
Total	9,382

The basis upon which the required amount of equipment was determined, is set forth for each service in the following:

Locomotive Passenger Service

A study of the through passenger schedules disclosed the number and frequency of the through passenger trains of each railroad operating within the limits of electrification. Facts thus obtained provided a basis upon which the number of locomotives required for through passenger service could be determined, the desired result being the number of locomotives required to protect all through schedules between the city terminus and the point at which provision is to be made for change of motive power, assuming that each train will operate on the schedule indicated by the time-table.

Multiple-Unit Passenger Service

A study of the suburban passenger schedules disclosed the number and frequency of the suburban trains of each railroad operating within the limits of electrification. Facts thus obtained provided a basis upon which the number of multiple-unit motor and trailer cars required to protect suburban schedules could be determined.

In the study of the requirements of this service, consideration was given to seating capacity, running time and other factors, in order that the assignment of electric equipment might be adequate to provide a service in every way equal to the present service. It was assumed that each schedule would be maintained as shown by the time-tables.

Road Freight Service

A study of the traffic handled in road freight service disclosed the number of locomotive-hours and trailing ton-miles for each hour of the average day, by roads. Facts thus obtained provided a basis upon which the number of locomotives necessary to meet the schedule requirements of this service for the average day could be determined.

Yard and Transfer Service

A study of the traffic handled in yard service, and freight and passenger transfer services, disclosed the number of locomotive-hours for each hour of the average day, by roads. Facts thus obtained provided a basis upon which the number of locomotives necessary to meet the schedule requirements of this service within the limits of electrification could be determined.

Influences Governing the Rolling Equipment Requirement

The demand for transportation service during certain hours of the day and certain days of the year, in excess of the average or normal demand, constitutes an important factor to be considered in determining the amount of rolling equipment required to handle the traffic of the terminals. The amount of traffic to be handled in the Chicago railroad terminals for the average day of the year 1912 has been determined. Its seasonal variation has also been determined and the relation of its flow for the average day to the flow for each day of the average week is known. A study of these factors has been necessary in connection with the determination of the number of locomotives required to handle the traffic under all conditions.

213.061 Locomotive Passenger Service: Locomotive passenger service embraces that service involved in the handling of through passenger traffic within the limits of electrification. Under electric operation, there will be a change of motive power in this service at the point which marks the outer limits of electric operation. In the present steam service no change of locomotives is ordinarily made between the city terminus and the first division point outside of the city. The average time now consumed by steam locomotives in through passenger service within the proposed limits of electrification is about 2.5 hours per day. At present there is, of course, no assignment of locomotives exclusively to the service within these limits. One locomotive generally protects two schedules, that is, it brings a train in and takes a train out. In a few cases one locomotive protects three or more schedules, but these instances are so few that they are negligible in their effect. On this basis, there are about 350 different steam locomotives handling through passenger trains each day within the proposed limits of electrification. The peak hours of the service occur in the periods from 6:00 A.M. to 9:00 A.M., and from 5:00 P.M. to 8:00 P.M. The extent and density of this service within the proposed limits of electrification under steam operation in October, 1912, were as follows:

Average number of train-miles per day	12,460
Average number of scheduled trains daily	704

The method used in determining the minimum number of electric locomotives required to protect locomotive passenger schedules is described in the following:

From the time-tables in effect on each road in October, 1912, each schedule was plotted on a chart, by means of which the minimum demands of the railroad could easily be noted, assuming:

1. That each train will be operated on the schedule shown by the time-table.
2. That, in considering the availability of an electric locomotive for the purpose of protecting a schedule, 30 minutes clear time will be allowed at the terminal for coupling or uncoupling and for getting the locomotive into position.
3. That the service of moving equipment between the station and the coach yard will ordinarily be handled by yard switching locomotives, but it may be found both possible and practicable to have at least part of this service performed by electric passenger locomotives during the time they are waiting for a schedule.

To the total minimum requirement of each road is added an arbitrary number of "spares" or extra locomotives to protect, first, ordinary inspection and repairs, and second, exigencies such as extra service, accidents, delays which may result in "bunching trains," and other contingencies which arise in the operation of a railroad. In determining the number of spares to provide against all of these conditions on each road, consideration was given to the following factors:

1. Where the minimum requirement is four locomotives or less, the number has been generally doubled on the assumption that exigencies such as accidents, delayed trains and extra service will so change the operating conditions as to make it impossible to protect schedules with a smaller number of locomotives.
2. Where the minimum requirement has been more than four locomotives, the method employed in determining the number of spares to protect exigencies has been to consider:
   - *a.* The number of schedules operated.
   - *b.* The length of the run.
   - *c.* The spread in time between schedules.
   - *d.* The operating conditions which obtain at the terminal with reference to the amount of time required in making an exchange of locomotives or a movement into position to protect a schedule.

On roads having 20 or more scheduled trains daily, one locomotive for each 12 schedules was generally regarded as ample to provide against exigencies outside of ordinary inspection and repairs.

It has been assumed that the electric locomotive will be available for service 20 hours per day. The 4 hours that the locomotive will be out of service, 17 per cent of its total time, will provide for daily inspection, cleaning and light repairs.

The electric locomotive for passenger service will require shopping for heavy repairs and overhauling every 60,000 miles. A shopping will require 18 days, or 3 per cent of the total time.

On these assumptions, the electric locomotive for passenger service will be performing service 80 per cent of the total time, the remaining 20 per cent being required for inspection and repairs.

After giving consideration to all the factors discussed in the preceding paragraphs, the number of electric locomotives required for locomotive passenger service, by roads, has been determined as shown by table CCCIV.

213.062 Multiple-Unit Passenger Service: This service, as distinguished from locomotive passenger service, will be operated entirely within the proposed limits of electrification, and multiple-unit motor and trailer cars will be used instead of electric locomotives. Equipment will be required for a daily service, the extent of which is shown by the following:

	AVERAGE NO.
Suburban trains daily	661
Train-miles daily, all suburban trains	11,328
Cars per train	4.4

The estimates relating to equipment for handling the multiple-unit or suburban service are based upon the removal from such service of the present equipment, since this equipment is of wood and is regarded as unsuitable for use in trains between steel motor cars. In working out the requirements of this service, each schedule has been plotted. A typical diagram of a suburban schedule is presented as fig. 647.

A minimum delay of ten minutes has been allowed on all schedules at terminals to get the equipment into position for the return movement.

TABLE CCCIV. NUMBER OF ELECTRIC LOCOMOTIVES REQUIRED FOR LOCOMOTIVE PASSENGER SERVICE, BY ROADS
(Based on the time-tables of October, 1912)

Railroad	Avg. No. Scheduled Trains Daily	Avg. No. Train-Miles Daily	Locomotives Required		
			Minimum to Meet Schedules	Spares	Totals
1	2	3	4	5	6
Atchison, Topeka & Santa Fe Railway	16	208	3	3	6
Baltimore & Ohio Railroad	12	386	3	3	6
Baltimore & Ohio Chicago Terminal Railroad	8	155	2	2	4
Chesapeake & Ohio Railway of Indiana	6	135	2	2	4
Chicago & Alton Railroad	18	185	4	3	7
Chicago & Eastern Illinois Railroad*	30	540	4	3	7
Chicago & Erie Railroad	11	248	3	3	6
Chicago & North Western Railway	171	3,170	30	12	42
Chicago, Burlington & Quincy Railroad	47	320	7	6	13
Chicago Great Western Railroad	8	83	2	2	4
Chicago, Indiana & Southern Railroad	6	145	2	2	4
Chicago, Indianapolis & Louisville Railway	14	326	3	3	6
Chicago, Milwaukee & St. Paul Railway	84	1,157	14	6	20
Chicago, Rock Island & Pacific Railway	30	471	4	4	8
Grand Trunk Western Railway	22	319	6	4	10
Illinois Central Railroad	50	718	8	5	13
Lake Shore & Michigan Southern Railway	38	1,132	9	6	15
Michigan Central Railroad	31	704	6	4	10
Minneapolis, St. Paul & Sault Ste. Marie Railway	14	112	3	3	6
New York, Chicago & St. Louis Railroad	6	154	2	2	4
Pere Marquette Railroad	10	215	3	2	5
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	43	1,054	6	3	9
Pittsburgh, Fort Wayne & Chicago Railway			6	3	9
Wabash Railroad	29	523	6	4	10
Totals	704	12,460	138	90	228

* Time-table of November 30, 1913.

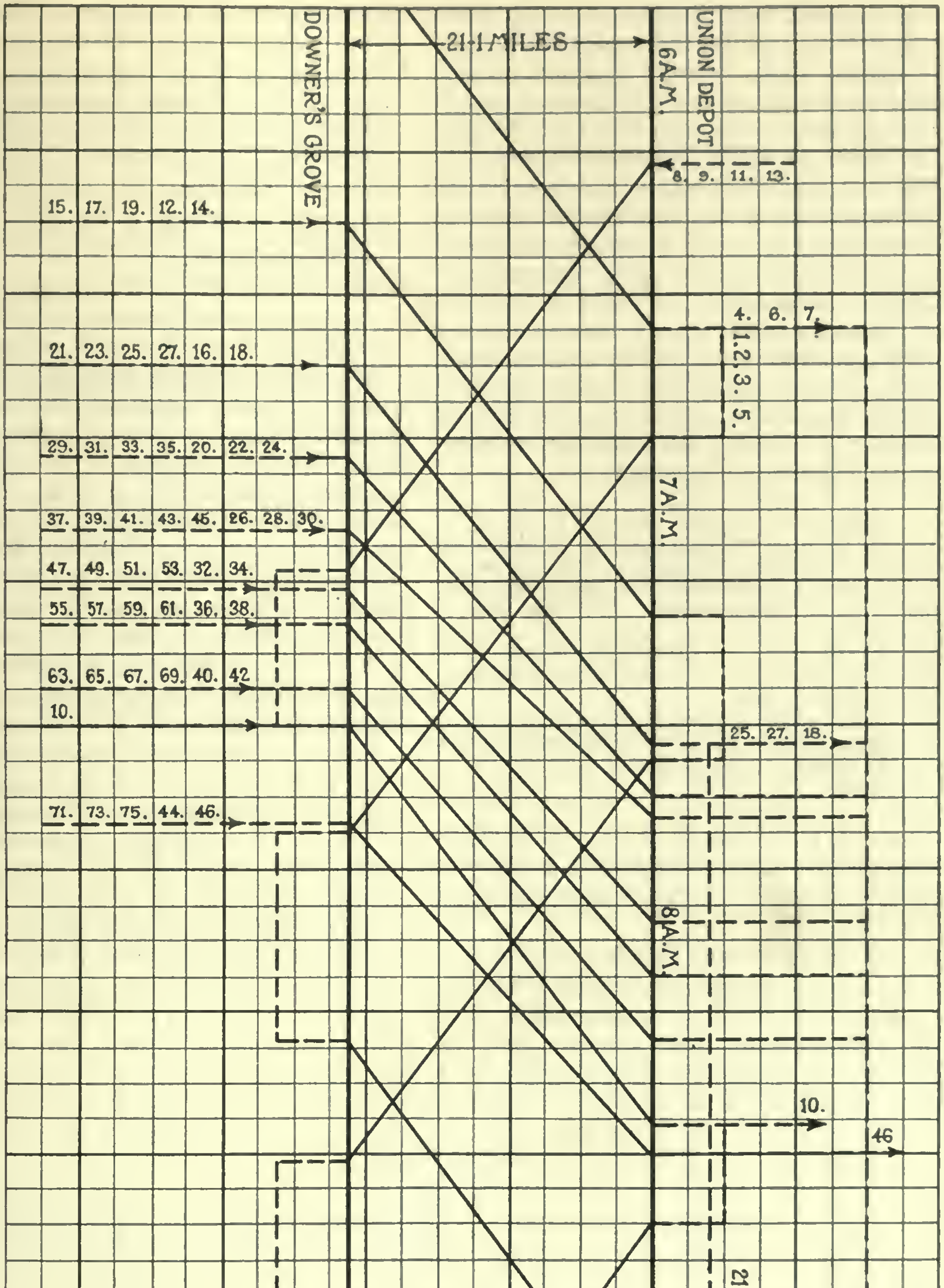

FIG. 647. TRAIN SHEET SHOWING METHOD USED TO DETERMINE SUBURBAN MOTOR AND TRAILER CAR REQUIREMENTS
(CHICAGO, BURLINGTON & QUINCY R. R.)
(Odd numbers indicate motor cars; even numbers, trailer cars)

In determining the amount of equipment necessary for this service, trains having about 10 per cent greater seating capacity than the present trains have been provided. The seating capacity of the cars and the make-up of trains to be used in this service are set forth in section 213.059.

The peak hours of suburban passenger service lie between 7:00 A.M. and 9:00 A.M. and between 5:00 P.M. and 7:00 P.M. Approximately 60 per cent of the total suburban service is performed during these four hours.

To the number of cars required to protect schedules, has been added 15 per cent to provide, first, for inspection and repairs, and second, for exigencies such as extra service, accidents and "bunching" of trains. This allowance is based upon the following considerations:

1. Each motor car will be available for service 24 hours per day, providing there are a sufficient number of schedules to keep it in constant service.
2. A motor car will require one general inspection for every 1,200 miles run. Each inspection will require one hour.
3. A motor car will require shopping for general repairs for every 45,000 miles run. A shopping will consume 14 days.
4. The inspection and ordinary repairs will consume about five per cent of the total time.
5. As a factor of safety to meet exigencies, 10 per cent has been added.

Table CCCV indicates the number of multiple-unit motor and trailer cars required for suburban passenger service by the seven roads operating this service.

213.063 Road Freight Service: Road freight service is defined as that service which involves the movement of freight cars between points within and points outside of the proposed limits of electrification. In this service, there will be a change of motive power at the point which marks the outer limits of electrification. There will be an assignment of electric locomotives exclusively for this service within these limits.

The number of train-miles and the number of trailing ton-miles for road freight service for the average day are shown by the following:

Total number of train-miles per day within the proposed limits of electrification	5,369
Average trailing load in tons per locomotive . . .	988
Average speed per hour in miles	9.4
Average number of trailing ton-miles per day . . .	5,668,326

Assuming that the electric locomotive will be available for service 20 hours per day and will handle the same trailing load at the same average speed as the steam locomotive, this service would require a total of 31 electric locomotives for the entire electrified trackage, if the traffic flowed regularly throughout the 24 hours. Between the hours of 12:00 midnight and 4:00 A.M., however, a maximum of only 23 locomotives is required at any one time; between 4:00 A.M. and 9:00 A.M. a maximum of 34 locomotives is required; between 9:00 A.M. and 6:00 P.M. the requirement drops to 23 locomotives working; and between 6:00 P.M. and 12:00 midnight the requirement increases to a maximum of 33 locomotives working.

The basis employed in determining the number of locomotives required for passenger service could not be applied to the determinations with reference to the locomotive requirements for road freight service, since very few of the road freight trains are shown on the time-tables. Therefore, in determining the number of electric locomotives required for this service, the maximum locomotive-hour for each road for the average day was employed as a basis. To the daily requirement was added 25 per cent to provide, first, for inspection and repairs, and second, for exigencies such as extra service, accidents and "bunching" of trains.

TABLE CCCV. NUMBER OF MULTIPLE-UNIT MOTOR AND TRAILER CARS REQUIRED FOR SUBURBAN PASSENGER SERVICE, BY ROADS

(Basis of 1912)

Railroad	Avg. No. Schedule Trains Daily	Avg. No. Train-Miles Daily	Motor Cars			Trailer Cars		
			Minimum to Meet Schedules	Spares	Total	Minimum to Meet Schedules	Spares	Total
1	2	3	4	5	6	7	8	9
Chicago & North Western Railway	175	3,338	138	21	159	77	12	89
Chicago & Western Indiana Railroad	30	421	23	4	27	14	3	17
Chicago, Burlington & Quincy Railroad	47	992	38	6	44	23	4	27
Chicago, Rock Island & Pacific Railway	78	1,250	46	7	53	23	4	27
Illinois Central Railroad	272	3,949	118	18	136	58	9	67
Lake Shore & Michigan Southern Railway	36	851	28	5	33	14	3	17
Pittsburgh, Fort Wayne & Chicago Railway	23	527	15	3	18	5	2	7
Totals	661	11,328	406	64	470	214	37	251

This allowance is based upon the following considerations:

1. It has been assumed that the electric locomotive will be available for service 20 hours per day. During the 4 hours that the locomotive is out of service, the daily inspection and light repairs can be made and such cleaning as is required can be done. This will amount to 17 per cent of the total time.
2. A period of 30 minutes at terminals is considered as constituting a minimum period for getting the locomotive in position to protect another movement.
3. The electric locomotive for road freight service will require shopping for heavy repairs and general overhauling every 44,000 miles. This shopping will require 18 days and will amount to 3.0 per cent of the total time. On this assumption, the electric locomotive for road freight service will be out of service 20 per cent of the total time.
4. As a factor of safety to cover exigencies, extra service and accidents, an allowance of 5 per cent has been added.

On this basis, the number of electric locomotives required to handle the road freight service for the 19 roads operating this service has been determined as shown by table CCCVI.

213.064 Yard and Transfer Service: This part of the transportation service is considered under two headings:

1. Yard service.
2. Freight and passenger transfer service.

Yard Service

Yard service involves the moving of cars from one location to another in yards, the placing of cars on, and their removal from, industrial tracks, team tracks and freight house tracks, and the assembling of cars in trains for movement to their destinations.

Locomotives engaged in yard service constitute about 84 per cent of the total number of locomotives engaged in yard and transfer service.

Yard service is extremely varied and irregular, its extent being dependent upon the demands or necessities of the industries, team tracks and freight houses served. A movement to place or to remove a single car may require the time of a yard locomotive and its crew for several hours.

The amount of yard service, expressed in locomotive-hours and trailing ton-miles, handled by the 30 roads having this service, and the total for the terminals are shown by table CCCVII.

The average daily activities of locomotives in yard service are shown by the following:

Average number of locomotives working	519
Number of locomotive-hours	7,625
Average number of hours working per locomotive .	14.7
Average trailing load per locomotive in tons . . .	306
Average speed in miles per hour	3.24
Number of locomotive-miles	24,782
Number of trailing ton-miles	7,560,200

Yard switching is performed in 152 yards or switching districts. In 26 yards or districts the maximum hour requirements exceed five locomotives, and in 51 yards the maximum hour requirements vary from two to five locomotives. In 75 yards, only one locomotive is required, and in 40 of these the requirements during any one hour of the day are less than one locomotive-hour. The total number of locomotives working in yard ser-

TABLE CCCVI. NUMBER OF ELECTRIC LOCOMOTIVES REQUIRED FOR ROAD FREIGHT SERVICE, BY ROADS
(Basis of 1912)

Railroad	Loco. Mileage Average Day	Loco. Hours of Service Average Day	Trailing Ton-Miles Average Day	Locomotives Required		Total
				Minimum No. Required in Service Average Day	Spares	
1	2	3	4	5	6	7
Atchison, Topeka & Santa Fe Railway	159	11	142,903	3	1	4
Baltimore & Ohio Railroad	252	32	305,489	4	1	5
Chicago & Alton Railroad	80	9	104,474	2	1	3
Chicago & Eastern Illinois Railroad	65	12	64,082	2	1	3
Chicago & North Western Railway	807	102	634,824	12	3	15
Chicago, Burlington & Quincy Railroad	241	24	36,285	5	1	6
Chicago Great Western Railroad	28	3	29,422	1	1	2
Chicago, Indianapolis & Louisville Railway	71	3	50,910	1	1	2
Chicago, Milwaukee & St. Paul Railway	437	45	511,132	8	2	10
Chicago, Rock Island & Pacific Railway	50	6	33,893	2	0	2
Grand Trunk Western Railway	210	13	190,958	2	0	2
Illinois Central Railroad	356	49	712,818	7	1	8
Lake Shore & Michigan Southern Railway	597	39	884,185	7	1	8
Michigan Central Railroad	59	5	63,725	2	1	3
New York, Chicago & St. Louis Railroad	232	19	172,472	3	1	4
Pere Marquette Railroad	41	6	29,318	1	1	2
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	655	55	561,041	6	1	7
Pittsburgh, Fort Wayne & Chicago Railway	689	71	811,436	7	1	8
Wabash Railroad	340	44	328,959	5	1	6
Totals	5,369	548	5,668,326	80	20	100

TABLE CCCVII. YARD SERVICE ON TRACKS TO BE ELECTRIFIED, FOR THE AVERAGE DAY, BY ROADS
(Basis of 1912)

Railroad	Locomotive-Hours	Trailing Ton-Miles
Atchison, Topeka & Santa Fe Ry	142	140,400
Baltimore & Ohio R. R	92	91,200
Baltimore & Ohio Chicago Terminal R. R	233	230,900
Calumet, Hammond & Southeastern R. R	30	29,700
Chicago & Alton R. R	161	159,600
Chicago & Calumet River R. R	33	32,300
Chicago & Eastern Illinois R. R	62	61,600
Chicago & North Western Ry	1,340	1,328,800
Chicago, Burlington & Quincy R. R	315	312,000
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	398	394,200
Chicago Great Western R. R	92	91,400
Chicago, Indianapolis & Louisville Ry	14	13,700
Chicago Junction Ry	672	666,000
Chicago, Milwaukee & St. Paul Ry	872	864,200
Chicago, Rock Island & Pacific Ry	311	308,700
Chicago, West Pullman & Southern R. R	108	107,000
Elgin, Joliet & Eastern Ry	486	482,000
Grand Trunk Western Ry	58	57,600
Illinois Central R. R	342	339,000
Illinois Northern Ry	45	45,100
Indiana Harbor Belt R. R	26	25,600
Lake Shore & Michigan Southern Ry	324	321,600
Michigan Central R. R	204	202,000
Minneapolis, St. Paul & Sault Ste. Marie Ry	20	19,800
New York, Chicago & St. Louis R. R	113	112,400
Pere Marquette R. R	79	78,400
Pittsburgh, Cincinnnti, Chicago & St. Louis Ry.	366	362,500
Pittsburgh, Fort Wayne & Chicago Ry	456	453,000
Pullman R. R	38	38,000
Wabash R. R	193	191,500
Totals	7,625	7,560,200

vice in the 152 yards varies during the different periods of the day. From 7:00 A.M. to 6:00 P.M. the number working at one time varies from 350 to 410, and from 6:00 P.M. to 7:00 A.M. from 210 to 290.

The extent of service performed and the number of yards served are set forth by roads in table CCCVIII.

Some of the larger classification yards within the Area of Investigation, such as the Proviso Yard of the Chicago & North Western Railway, the Burr Oak Yard of the Chicago, Rock Island & Pacific Railway, the Dolton Yard of the Chicago & Eastern Illinois Railroad, and the Glenn Yard of the Chicago & Alton Railroad, are located beyond the proposed limits of electrification, and will continue to be operated by steam locomotives.

Freight and Passenger Transfer Service

Transfer service involves the movement of cars from one railroad to another, and from one yard to another on the same railroad when the yards are not contiguous. Transfer service generally involves the movement of cars in trains, with less frequent stops and consequently with a higher degree of locomotive efficiency than is the case in yard service.

At present there are no locomotives set aside for transfer service exclusively. Some roads perform transfer work with the regular yard locomotive, while others, where conditions are favorable, use a heavier type of locomotive. The general method followed is to assemble the transfer train with the yard locomotive and deliver it to the transfer locomotive for movement to its

TABLE CCCVIII. EXTENT AND DISTRIBUTION OF YARD SERVICE, BY ROADS
(Basis of 1912)

Railroad	Locomotive-Hours of Service, Average Day	No. of Yards Reported within Limits of Electrification	No. of Yards in which the Maximum Time of Service for the Avg. Day is		
			One Hour and Less	Over One Hour and Less than 6 Hours	6 Hours and Over
1	2	3	4	5	6
Atchison, Topeka & Santa Fe Railway	142	2	0	1	1
Baltimore & Ohio Railroad	92	1	0	0	1
Baltimore & Ohio Chicago Terminal Railroad	233	2	0	1	1
Calumet, Hammond & Southeastern Railroad	30	1	0	1	0
Chicago & Alton Railroad	161	3	1	1	1
Chicago & Calumet River Railroad	33	1	0	1	0
Chicago & Eastern Illinois Railroad	63	3	1	2	0
Chicago & North Western Railway	1,340	17	9	5	3
Chicago & Western Indiana Railroad and the Belt Railway of Chicago	398	7	3	3	1
Chicago, Burlington & Quincy Railroad	315	16	11	3	2
Chicago Great Western Railroad	92	1	0	0	1
Chicago, Indianapolis & Louisville Railway	14	1	1	0	0
Chicago Junction Railway	672	7	2	1	4
Chicago, Milwaukee & St. Paul Railway	871	12	5	4	3
Chicago, Rock Island & Pacific Railway	311	3	2	1	0
Chicago, West Pullman & Southern Railroad	108	2	1	1	0
Elgin, Joliet & Eastern Railway	486	2	0	1	1
Grand Trunk Western Railway	58	1	0	1	0
Illinois Central Railroad	342	4	0	3	1
Illinois Northern Railway	45	2	1	1	0
Indiana Harbor Belt Railroad	26	1	0	1	0
Lake Shore & Michigan Southern Railway	324	32	26	5	1
Michigan Central Railroad	204	4	2	1	1
Minneapolis, St. Paul & Sault Ste. Marie Railway	20	1	1	0	0
New York, Chicago & St. Louis Railroad	113	3	1	1	1
Pere Marquette Railroad	79	2	0	2	0
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	366	7	3	2	2
Pittsburgh, Fort Wayne & Chicago Railway	456	9	4	4	1
Pullman Railroad	38	1	0	1	0
Wabash Railroad	193	4	1	3	0
Totals	7,625	152	75	51	26

destination. Upon arriving at its destination, the transfer locomotive is either given another train for movement to some other point or is assigned to yard service. The two services are so closely related as to make it undesirable to consider them as separate factors in apportioning locomotives. The volume of transfer service, by roads, for the average day in 1912 is shown by table CCCIX.

The average daily activities of locomotives in freight transfer service are shown by the following:

Average number of locomotives working	113
Number of locomotive-hours	1,617
Average number of working hours per locomotive	14.3
Average trailing load per locomotive, in tons	811
Average speed in miles per hour	5.7
Number of locomotive-miles	8,838
Number of trailing ton-miles	7,502,341

The electric locomotive selected as a basis for the Committee's estimates is capable of accelerating its load in a degree not possessed by the steam locomotives now in service. It will start more quickly and attain its maximum speed in a shorter space of time. It has been suggested that this fact will make it possible for a given switching service to be performed by a smaller number of electric locomotives than of steam locomotives, but a study of the traffic flow and traffic density in the Chicago terminals shows that this basis of comparison is not generally applicable. In yards where the density of traffic is such as to require a considerable number of units, and where the flow of the traffic is sufficiently uniform to supply the required amount of work for the electric locomotive, the superior accelerating ability of electric locomotives will make it possible to reduce the total number of units employed. The number of yards in which such conditions exist, however, is small. In many yards the traffic is neither dense nor uniform, and the full time of the steam locomotives is not now being utilized. Under such conditions, the superiority of the electric locomotive does not become effective in permitting a reduction in the number of units required to handle the traffic.

The exact amount of time which can be gained by the use of electric locomotives under conditions of dense and uniform traffic in yards is, under present conditions, indeterminate, and the Committee does not attempt to make assumptions based upon operating conditions other than those which exist at present. There exists no example of electrically operated yard service directly comparable with that of the large yards of Chicago. In the absence of definite data, a careful study has been made of traffic conditions in Chicago and of the possibilities of saving time by the substitution of the electric locomotive for the steam locomotive, which has led to the conclusion that the greater accelerating capabilities of the electric locomotive cannot be regarded as a factor of significance in determining the number of units required in yard service in the Chicago terminals.

TABLE CCCIX. FREIGHT TRANSFER SERVICE ON TRACKS TO BE ELECTRIFIED, FOR THE AVERAGE DAY, BY ROADS

(Basis of 1912)

Railroad 1	Locomotive-Miles 2	Locomotive-Hours of Service 3	Trailing Ton-Miles 4
Atchison, Topeka & Santa Fe Railway	136	23	41,070
Baltimore & Ohio Railroad	232	34	199,031
Baltimore & Ohio Chicago Terminal Railroad	398	91	416,488
Chesapeake & Ohio Railway of Indiana	42	5	37,148
Chicago & Alton Railroad	206	37	88,581
Chicago & Eastern Illinois Railroad	182	44	251,904
Chicago & North Western Railway	1,132	162	942,857
Chicago & Western Indiana Railroad and the Belt Ry. of Chicago	1,403	228	2,135,422
Chicago, Burlington & Quincy Railroad	664	117	368,145
Chicago Great Western Railroad	39	6	10,397
Chicago, Indianapolis & Louisville Railway	158	19	129,176
Chicago, Milwaukee & St. Paul Railway	749	217	568,401
Chicago, Rock Island & Pacific Railway	546	108	329,227
Chicago, West Pullman & Southern Railroad	17	5	6,212
Elgin, Joliet & Eastern Railway	56	6	123,492
Grand Trunk Western Railway	70	11	32,859
Illinois Central Railroad	342	58	325,982
Illinois Northern Railway	30	14	16,667
Indiana Harbor Belt Railroad	131	21	134,967
Lake Shore & Michigan Southern Railway	397	72	180,427
Manufacturers' Junction Railway	13	3	2,209
Michigan Central Railroad	392	48	254,616
Minneapolis, St. Paul & Sault Ste. Marie Railway	85	18	58,094
New York, Chicago & St. Louis Railroad	220	66	133,187
Pere Marquette Railroad	106	15	81,995
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	525	78	256,942
Pittsburgh, Fort Wayne & Chicago Railway	371	80	258,226
Wabash Railroad	196	31	118,619
Totals	8,838	1,617	7,502,341

In determining the total number of electric locomotives required to perform the yard and transfer service of the Chicago terminals, it has been assumed that the traffic will have the same flow and that it will be handled in the same average loads and at the same average rate of speed as the present steam service.

The experience of roads using electric locomotives in yard and transfer service indicates that this type of locomotive is capable of 20 hours of service as a maximum daily average between general repair periods.

Upon this basis, a locomotive-hour curve has been plotted for each road, and the number of electric locomotives required to handle the yard and transfer service of the road in question has been determined. One of these diagrams is presented as fig. 648.

The maximum time an electric locomotive is available for work in yard service during any 24-hour period has been fixed at 20 hours. Operation is assumed to begin at midnight, with a certain number of locomotives, and each hour thereafter additional locomotives are placed in service or removed from service as the flow of traffic or the physical limitations of the locomotive may require.

According to the reports furnished by the railroads, the number of hours of service obtained from each steam locomotive in yard and transfer service for the average day shows great variation for different roads, ranging from 11.3 hours as a minimum to 20.7 hours as a maximum, the average for all roads being 14.5 hours per locomotive per day. The peak period of service lies between 8:00 A.M. and 4:00 P.M. During each hour of this period 500 to 520 locomotives are working within the proposed limits of electrification, excepting between 12:00 noon and 2:00 P.M., during which period the number decreases to 485.

The irregular flow of traffic and the varying service requirements at different periods of the day for individual roads prevent the full utilization of the available service time of the locomotive. The reports for the Chicago terminals indicate that each steam locomotive in service in 1912 worked, on the average, 14.5 hours per day. If it is assumed that 16 hours per day constitutes the maximum available time of a steam locomotive between general shopping periods, the average time worked by steam locomotives in 1912 was nearly 91 per cent of the available time. Under electric traction the electric locomotive will work, on the average, 16.5 hours per day, or 83 per cent of its available time. The loss in percentage of available time utilized is due to an increase of four hours, or 25 per cent, in the available service time. Inability to utilize all of this increase is due to the flow of traffic and to the service requirements. The reduction in the number of locomotives required to perform the same volume of service is not the result of a reduction in the number of locomotive-hours, but is due to an increase in the number of hours per locomotive.

To the average daily locomotive requirement has been added 20 per cent to protect, first, ordinary inspection, cleaning and repairs, and second, exigencies, such as extra service and accidents. This allowance is based upon the following considerations:

1. A general inspection requiring about 12 hours will be necessary every 10 days.
2. Each electric locomotive will require, for every 15 months of service, one shopping for general repairs, which will consume 18 days.
3. General inspection and general shopping will consume about 9 per cent of the total time of the locomotive.
4. Eleven per cent is thought to be a reasonable amount to add to the average daily requirement for each road as a factor of safety to provide for possible extra service and accidents.

On this basis, the total number of electric locomotives required to handle yard and transfer service for the roads operating such service, has been determined as shown by table CCCX.

213.065 Summary of the Number of Electric Locomotives and Multiple-Unit Cars Required to Operate the Chicago Terminals: The number of electric locomotives and multiple-unit cars required to operate the terminals of Chicago, as they existed in 1912, is shown by table CCCXI.

213.066 Work and Inspection Equipment: In preparing estimates of the cost of work and inspection equipment, the Committee has assumed that the work equipment now used for steam service may, under electrification, continue to be used for a similar purpose and in the same general manner as at present, and that steam locomotives

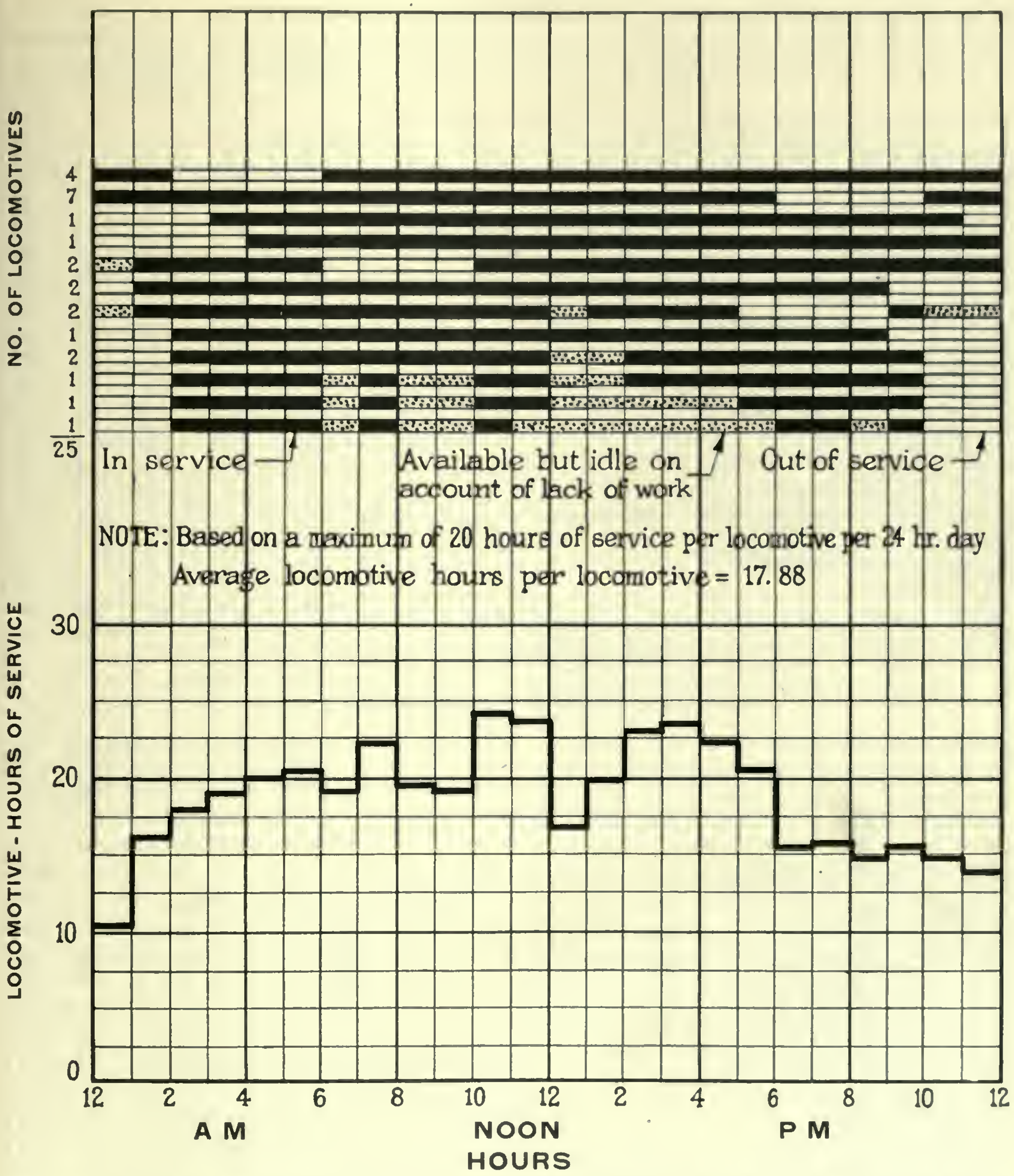

FIG. 648. STEAM LOCOMOTIVE-HOURS OF SERVICE AND NUMBER OF ELECTRIC LOCOMOTIVES REQUIRED FOR THE AVERAGE DAY FOR YARD, FREIGHT TRANSFER AND PASSENGER TRANSFER SERVICES (CHICAGO, BURLINGTON & QUINCY R. R.)

TABLE CCCX. NUMBER OF ELECTRIC LOCOMOTIVES REQUIRED FOR YARD AND TRANSFER SERVICE, BY ROADS

(Basis of 1912)

Railroad	Loco.-Hours of Service Average Day	Avg. Hours Worked Daily by Each Electric Locomotive	Locomotives Required		
			Minimum No. Required in Service, Avg. Day	Spares	Total
1	2	3	4	5	6
Atchison, Topeka & Santa Fe Railway	169	16.9	10	2	12
Baltimore & Ohio Railroad	126	15.7	8	2	10
Baltimore & Ohio Chicago Terminal Railroad	324	18.0	18	4	22
Calumet, Hammond & Southeastern Railroad	30	15.0	2	1	3
Chesapeake & Ohio Railway of Indiana	5	2.5	2	1	3
Chicago & Alton Railroad	204	13.6	15	3	18
Chicago & Calumet River Railroad	33	16.5	2	1	3
Chicago & Eastern Illinois Railroad	106	15.1	7	1	8
Chicago & Erie Railroad*	.....	....	1	1	2
Chicago & North Western Railway	1,528	18.4	83	16	99
Chicago & Western Indiana Railroad and the Belt Railway of Chicago	639	17.2	37	7	44
Chicago, Burlington & Quincy Railroad	447	17.9	25	5	30
Chicago Great Western Railroad	98	14.0	7	1	8
Chicago, Indiana & Southern Railroad †	.....	....	...	...	...
Chicago, Indianapolis & Louisville Railway	33	11.0	3	1	4
Chicago Junction Railway	672	17 7	38	7	45
Chicago, Milwaukee & St. Paul Railway	1,106	17.5	63	12	75
Chicago River & Indiana Railroad ‡	.....	....	...	...	...
Chicago, Rock Island & Pacific Railway	428	15.3	28	5	33
Chicago Short Line Railway *	.....	....	2	1	3
Chicago Union Transfer Railway ¶	.....	....	...	...	...
Chicago, West Pullman & Southern Railroad	113	16.1	7	1	8
Elgin, Joliet & Eastern Railway	492	17.0	29	6	35
Grand Trunk Western Railway	71	14 2	5	1	6
Illinois Central Railroad	401	14.3	28	6	34
Illinois Northern Railway	59	9.8	6	1	7
Indiana Harbor Belt Railroad	47	7 8	6	1	7
Lake Shore & Michigan Southern Railway	411	17.9	23	5	28
Michigan Central Railroad	255	17.0	15	3	18
Minneapolis, St. Paul & Sault Ste. Marie Railway	38	9.5	4	1	5
New York, Chicago & St. Louis Railroad	192	13.7	14	3	17
Pere Marquette Railroad	94	15.7	6	1	7
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	444	16 4	27	5	32
Pittsburgh, Fort Wayne & Chicago Railway	552	16.7	33	7	40
Pullman Railroad	38	9 5	4	1	5
Wabash Railroad	224	16 0	14	3	17
Totals	9,379	16.5	572	116	688

* Did not report. The number of locomotives required has been estimated. † Included in the estimates for the Lake Shore & Michigan Southern Railway. ‡ Included in the estimates for the Chicago Junction Railway. ¶ Included in the estimates for the Chicago & Western Indiana Railroad.

TABLE CCCXI. SUMMARY, BY ROADS, OF THE NUMBER OF ELECTRIC LOCOMOTIVES AND MULTIPLE-UNIT CARS REQUIRED TO OPERATE THE CHICAGO TERMINALS

(Basis of 1912)

Railroad	Locomotives				Multiple-Unit Cars		
	Yard	Freight	Passenger	Total	Motor Cars	Trailer Cars	Total
1	2	3	4	5	6	7	8
Atchison, Topeka & Santa Fe Railway	12	4	6	22	.....	.....	.....
Baltimore & Ohio Railroad	10	5	6	21	.....	.....	.....
Baltimore & Ohio Chicago Terminal Railroad	22	.....	4	26	.....	.....	.....
Calumet, Hammond & Southeastern Railroad	3	.....	.....	3	.....	.....	.....
Chesapeake & Ohio Railway of Indiana	3	.....	4	7	.....	.....	.....
Chicago & Alton Railroad	18	3	7	28	.....	.....	.....
Chicago & Calumet River Railroad	3	.....	.....	3	.....	.....	.....
Chicago & Eastern Illinois Railroad	8	3	7	18	.....	.....	.....
Chicago & Erie Railroad	2	.....	6	8	.....	.....	.....
Chicago & North Western Railway	99	15	42	156	159	89	248
Chicago & Western Indiana Railroad and the Belt Railway of Chicago	44	.....	.....	44	27	17	44
Chicago, Burlington & Quincy Railroad	30	6	13	49	44	27	71
Chicago Great Western Railroad	8	2	4	14	.....	.....	.....
Chicago, Indiana & Southern Railroad	.....	.....	4	4	.....	.....	.....
Chicago, Indianapolis & Louisville Railway	4	2	6	12	.....	.....	.....
Chicago Junction Railway	45	.....	.....	45	.....	.....	.....
Chicago, Milwaukee & St. Paul Railway	75	10	20	105	.....	.....	.....
Chicago Rock Island & Pacific Railway	33	2	8	43	53	27	80
Chicago Short Line Railway	3	.....	.....	3	.....	.....	.....
Chicago Union Transfer Railway*	.....	.....	.....	.....	.....	.....	.....
Chicago, West Pullman & Southern Railroad	8	.....	.....	8	.....	.....	.....
Elgin, Joliet & Eastern Railway	35	.....	.....	35	.....	.....	.....
Grand Trunk Western Railway	6	2	10	18	.....	.....	.....
Illinois Central Railroad	34	8	13	55	136	67	203
Illinois Northern Railway	7	.....	.....	7	.....	.....	.....
Indiana Harbor Belt Railroad	7	.....	.....	7	.....	.....	.....
Lake Shore & Michigan Southern Railway	28	8	15	51	33	17	50
Michigan Central Railroad	18	3	10	31	.....	.....	.....
Minneapolis, St. Paul & Sault Ste. Marie Railway	5	.....	6	11	.....	.....	.....
New York, Chicago, & St. Louis Railroad	17	4	4	25	.....	.....	.....
Pere Marquette Railroad	7	2	5	14	.....	.....	.....
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	32	7	9	48	.....	.....	.....
Pittsburgh, Fort Wayne & Chicago Railway	40	8	9	57	18	7	25
Pullman Railroad	5	.....	.....	5	.....	.....	.....
Wabash Railroad	17	6	10	33	.....	.....	.....
Totals	688	100	228	1.016	470	251	721

*Included with the yard locomotives estimated for the Chicago & Western Indiana Railroad.

are to be used to handle steam operated wrecking equipment. It is also assumed that some of the additional work equipment to be provided under electrification is to be hauled over the road by steam locomotives.

Line Inspection Cars

For the two overhead contact systems, it will be necessary to provide small gasoline inspection cars which can be used by electrical inspectors who will systematically cover the lines, and by repair men who will be required to reach quickly any point where defects have developed. These cars are arranged to carry, in addition to several men, light tool equipment including ladders, blocks, tackle and a limited amount of repair parts and fittings for the overhead construction. One car is to be provided for each 10 miles of route and an additional car for each large yard. A shelter is to be provided for each car. These will be placed at intervals of about ten miles along the railroad routes, usually at points coinciding with the locations of substations or switching stations. These shelters will also accommodate the tools and supplies.

Repair Trains

For repairs to the overhead contact system, both for the 2,400-volt direct current and the 11,000-volt alternating current systems, repair trains will be required. These trains will each consist of three cars, a box car, a flat car and a cabin car, and will be handled by a steam locomotive. Old cars may be used for this purpose. The box car is to be equipped with a work bench and with bins for material and tools and is to have a stationary platform on top extending the full width of the car. The flat car is to be equipped as a tower car having a platform adjustable as to height. On this car there will also be racks for reels of wire. The third or cabin car is to have a dummy pantograph on top for gaging the height of the contact wire and is to be arranged to serve as quarters for the train and emergency crews. One repair train is to be provided for each 200 miles of track. When not in active use, each repair train will stand on a siding conveniently central to the district assigned to the train, where it will at all times be ready for immediate service.

The amount of work equipment required in connection with electric operation of the railroad terminals of Chicago, in addition to that now in use for steam operation, based upon conditions which obtained on December 31, 1912, is shown by table CCCXII.

TABLE CCCXII. WORK EQUIPMENT REQUIRED FOR ELECTRIC OPERATION OF THE CHICAGO TERMINALS
(Basis of 1912)

Equipment	2,400-Volt D. C.	11,000-Volt A. C.
Line inspection cars	73	73
Repair trains	17	17

213.067 Unit Costs: To obtain the costs of the electric equipment described in the preceding sections, quotations obtained from manufacturers have been reviewed by the Committee's consulting electrical engineers in the light of contract prices for similar equipment purchased in the past or now under contract. The results thus obtained, including cost of delivery in Chicago, are presented by table CCCXIII.

TABLE CCCXIII. UNIT PRICES FOR ELECTRIC EQUIPMENT DELIVERED IN CHICAGO
(Basis of 1912)

Item	2,400-Volt D. C.	11,000-Volt A. C.
Yard locomotives	$ 30,000	$ 33,000
Freight locomotives	42,000	50,000
Passenger locomotives	59,500	67,500
Multiple-unit motor cars	20,200	20,100
Multiple-unit trailer cars	10,400	10,400
Line inspection cars including tool equipment and shelter	475	475
Repair trains, excluding locomotive	5,000	5,000

213.068 Estimated Costs of Electric Equipment on the Basis of the Traffic Requirements of 1912, Excluding all Allowances for Contingencies and for Engineering: The costs of electric locomotives, multiple-unit equipment and work and inspection equipment, necessary to operate the terminals of Chicago on the basis of the requirements reported for 1912, excluding all allowances for contingencies and for engineering, have been determined as set forth by tables CCCXIV and CCCXV.

TABLE CCCXIV. ESTIMATED COSTS OF ELECTRIC LOCOMOTIVES AND MULTIPLE-UNIT CARS REQUIRED FOR THE ELECTRIC OPERATION OF THE CHICAGO TERMINALS
(Basis of 1912)

Item 1	Number 2	2,400-Volt D. C. 3	11,000-Volt A. C. 4
Locomotives	688	$20,640,000	$22,704,000
Freight locomotives	100	4,200,000	5,000,000
Passenger locomotives	228	13,566,000	15,390,000
Multiple-unit motor cars	470	9,494,000	9,447,000
Multiple-unit trailer cars	251	2,610,400	2,610,400
Totals	..	$50,510,400	$55,151,400

In distributing the costs of rolling equipment among the roads involved, the cost of the line

TABLE CCCXV. ESTIMATED COSTS OF WORK AND INSPECTION EQUIPMENT REQUIRED FOR THE ELECTRIC OPERATION OF THE CHICAGO TERMINALS, BOTH THE 2,400-VOLT D. C. AND THE 11,000-VOLT A. C. SYSTEMS
(Basis of 1912)

Item	Quantity	Unit Cost	Amount
1	2	3	4
Line inspection cars	73	$ 475	$ 34,675
Repair trains	17	5,000	85,000
Totals			$119,675

inspection cars required for main track has been distributed on the basis of route mileage and the cost of those required for large yards has been distributed according to the ownership of the yards involved. The cost of repair trains has been distributed on the basis of track mileage. The cost of work equipment assigned to privately owned industrial tracks has been included with the costs shown for the road to which such tracks are adjacent. The estimated costs of all rolling equipment, by roads, excluding all allowances for contingencies and for engineering, are set forth in table CCCXVI.

TABLE CCCXVI. ESTIMATED COSTS OF ALL ELECTRIC ROLLING EQUIPMENT, INCLUDING LOCOMOTIVES, MOTOR AND TRAILER CARS, AND WORK AND INSPECTION EQUIPMENT, BY ROADS
(Basis of 1912)

Railroad	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3
Atchison, Topeka & Santa Fe Ry	$ 888,229	$ 1,004,229
Baltimore & Ohio R. R	869,251	987,251
Baltimore & Ohio Chicago Terminal R. R	902,529	1,000,529
Calumet, Hammond & Southeastern R. R	90,146	99,146
Chesapeake & Ohio Ry. of Indiana	328,004	369,004
Chicago & Alton R. R	1,084,435	1,218,435
Chicago & Calumet River R. R	90,520	99,520
Chicago & Eastern Illinois R. R	783,122	887,122
Chicago & Erie R. R	417,975	471,975
Chicago & North Western Ry	10,254,421	10,991,521
Chicago & Western Indiana R.R. and the Belt Ry. of Chicago	2,052,410	2,181,710
Chicago, Burlington & Quincy R. R	3,101,104	3,338,704
Chicago Great Western R. R	562,509	634,509
Chicago, Indiana & Southern R. R	238,521	270,521
Chicago, Indianapolis & Louisville Ry	561,307	637,307
Chicago Junction Ry	1,355,945	1,490,945
Chicago, Milwaukee & St. Paul Ry	3,869,609	4,334,609
Chicago River & Indiana R. R	310	310
Chicago, Rock Island & Pacific Ry	2,906,264	3,079,964
Chicago Short Line Ry	90,131	99,131
Chicago Union Transfer Ry	369	369
Chicago, West Pullman & Southern R. R	240,442	264,442
Elgin, Joliet & Eastern Ry	1,053,408	1,158,408
Grand Trunk Western Ry	861,564	975,564
Illinois Central R. R	5,585,515	5,841,915
Illinois Northern Ry	210,684	231,684
Indiana Harbor Belt R. R	211,052	232,052
Lake Shore & Michigan Southern Ry	2,917,857	3,182,557
Michigan Central R. R	1,263,707	1,421,707
Minneapolis, St. Paul & Sault Ste. Marie Ry	507,000	570,000
New York, Chicago & St. Louis R. R	918,092	1,033,092
Pere Marquette R. R	591,740	668,740
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	1,794,724	2,018,724
Pittsburgh, Fort Wayne & Chicago Ry	2,516,049	2,770,249
Pullman Railroad	151,438	166,438
Wabash Railroad	1,359,692	1,538,692
Totals	$50,630,075	$55,271,075

213.069 Estimated Total Cost of Electric Rolling Equipment: The estimated total cost of electric equipment, including locomotives, multiple-unit cars, trailer cars for the multiple-unit service, and the work and inspection equipment, which will be needed for the electric operation of the Chicago railroad terminals, is based upon the values set forth in the preceding estimates as determined for the conditions of 1912, extended in a manner normal to these estimates (chapter 212), the factors of extension in this case being as follows:

	PER CENT
1. To cover growth in traffic and mileage of railroads, December 31, 1912, to December 31, 1922	30.0
2. Contingencies	10.0
3. Engineering, design, supervision and administration	5.0
4. Interest, insurance and taxes during construction, at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

The values thus derived may be accepted as the total costs of electric rolling equipment on the basis of the requirements for 1922. These costs segregated by roads for both the 2,400-volt direct current and the 11,000-volt alternating current systems are set forth in table CCCXVII.

SPARE PARTS

213.070 General Considerations: The estimated cost of the power station (section 213.005) includes the cost of a spare generating unit, several boilers, a set of step-up transformers and auxiliaries, providing a reserve of such size that the failure of any part while in service, necessitating its withdrawal for repairs or inspection, will not reduce the available capacity of the plant below the point of maximum peak load.

The estimates of cost of substations (section 213.016) provide for a sufficient number of spare transformers and rotary converters at each location to supply any deficiency which may result from the failure of any unit. Such spare equipment for substations will be sufficient to maintain the capacity of the plant under maximum load conditions.

In determining the number of electric locomotives and multiple-unit cars upon which the estimate of cost of rolling equipment has been based (section 213.068), allowance has been made for the spare units required for shopping and emergencies.

In addition to the cost of the several items for the new plant and of the equipment referred to

TABLE CCCXVII. ESTIMATED TOTAL COST OF ELECTRIC ROLLING EQUIPMENT REQUIRED FOR THE ELECTRIC OPERATION OF THE CHICAGO TERMINALS, BY ROADS
(Dec. 31, 1922)

Railroad	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3
Atchison, Topeka & Santa Fe Ry	$ 1,473,714	$ 1,666,177
Baltimore & Ohio R. R	1,442,226	1,638,007
Baltimore & Ohio Chicago Terminal R. R.	1,497,440	1,660,038
Calumet, Hammond & Southeastern R. R.	149,567	164,499
Chesapeake & Ohio Ry. of Indiana	544,211	612,237
Chicago & Alton R. R	1,799,251	2,021,579
Chicago & Calumet River R. R.	150,187	165,120
Chicago & Eastern Illinois R. R.	1,299,325	1,471,877
Chicago & Erie R. R.	693,487	783,082
Chicago & North Western Ry	17,013,725	18,236,693
Chicago & Western Indiana R.R. and the Belt Ry. of Chicago	3,405,277	3,619,806
Chicago, Burlington & Quincy R. R	5,145,228	5,539,444
Chicago Great Western R. R.	933,292	1,052,752
Chicago, Indiana & Southern R. R	395,745	448,838
Chicago, Indianapolis & Louisville Ry	931,298	1,057,394
Chicago Junction Ry	2,249,730	2,473,716
Chicago, Milwaukee & St. Paul Ry	6,420,300	7,191,810
Chicago River & Indiana R. R	514	514
Chicago, Rock Island & Pacific Ry	4,821,957	5,110,153
Chicago Short Line Ry	149,542	164,474
Chicago Union Transfer Ry	612	612
Chicago, West Pullman & Southern R. R	398,932	438,752
Elgin, Joliet & Eastern Ry	1,747,772	1,921,984
Grand Trunk Western Ry	1,429,473	1,618,617
Illinois Central R. R.	9,267,263	9,692,672
Illinois Northern Ry	349,558	384,401
Indiana Harbor Belt R. R	350,169	385,011
Lake Shore & Michigan Southern Ry	4,841,192	5,280,371
Michigan Central R. R.	2,096,692	2,358,839
Minneapolis, St. Paul & Sault Ste. Marie Ry.	841,194	945,721
New York, Chicago & St. Louis R. R	1,523,262	1,714,065
Pere Marquette R. R.	981,791	1,109,547
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	2,977,734	3,349,386
Pittsburgh, Fort Wayne & Chicago Ry	4,174,528	4,596,286
Pullman Railroad	251,260	276,147
Wabash Railroad	2,255,947	2,552,936
Totals	$84,003,395	$91,703,557

in the preceding sections, it will be necessary to provide a supply of spare parts to be held in stock and issued as may be required.

For the power station these parts will include such items as turbine bearings, armature coils, parts of circuit breakers, switches, bus-bars, insulators, lengths of cables, tubes for condensers, tubes for boilers, grate bars for stokers, an assortment of various sizes of pipe, valves and fittings, impellers and shafts for circulating pumps, miscellaneous parts of feed pumps, spare armatures for motors, parts of the coal handling plant and other similar small equipment.

For substations and switching stations the parts to be carried in stock will include one extra transformer of each size, which may be transferred from station to station as required, parts of circuit breakers, switches, bus-bars, lightning arresters, bearings for rotary converters and sets of armature and field coils.

For the overhead contact system and the transmission line the estimate provides for a stock of extra insulators of each type, several miles of each size and class of wire and steel strand, an assortment of steel poles, brackets and cross-arms, section breaks, disconnecting switches and similar supplies.

For locomotives and car equipment the stock of spare parts will include a few additional motors, several extra control groups and other control apparatus, several spare armatures and spare armature coils, spare transformers and coils, extra brake parts, and miscellaneous details such as controller fingers, packing leathers, bushings, gaskets and other mechanical and electrical parts.

213.071 Estimated Costs of Spare Parts on the Basis of the Requirements of 1912, Excluding all Allowances for Contingencies and for Engineering: The estimated costs, excluding all allowances for contingencies and for engineering, of the spare parts required for both the 2,400-volt direct current and the 11,000-volt alternating current systems, are set forth in table CCCXVIII.

TABLE CCCXVIII. ESTIMATED COSTS OF SPARE PARTS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING
(Basis of 1912)

Item	2,400-Volt D.C.	11,000-Volt A.C.
For power station	$ 45,000	$ 45,000
For substations	45,000	35,000
For transmission lines and overhead contact system	12,000	12,000
For electric locomotives	115,000	115,000
For multiple-unit cars	80,000	80,000
Totals	$297,000	$287,000

213.072 Estimated Total Cost of Spare Parts: The estimated total cost of the spare parts for the electric operation of the Chicago railroad terminals is based upon the cost of labor and materials as determined for 1912, extended in the same manner and subject to the same factors of extension as were the costs of the plant or facility for which the spare parts are required.

The values thus derived may be accepted as the total costs on the basis of the requirements of 1922. These costs have been divided among the several railroads to be served, on the same basis as the costs of the plant or facility for which the spare parts are required.

The total cost, by railroads, of the spare parts is set forth for both the 2,400-volt direct current system and the 11,000-volt alternating current system, by table CCCXIX.

The fact should be emphasized that the cost of spare parts, as exhibited by roads in table

TABLE CCCXIX. ESTIMATED TOTAL COST OF SPARE PARTS, BY ROADS
(Dec. 31, 1922)

Railroad	2,400-Volt D.C.	11,000-Volt A. C.
1	2	3
Atchison, Topeka & Santa Fe Ry.	$ 6,271	$ 6,060
Baltimore & Ohio R. R.	6,051	5,794
Baltimore & Ohio Chicago Terminal R. R.	8,638	8,306
Calumet, Hammond & Southeastern R. R.	938	914
Chesapeake & Ohio Ry. of Indiana	1,718	1,662
Chicago & Alton R. R.	7,846	7,594
Chicago & Calumet River R. R.	919	898
Chicago & Eastern Illinois R. R.	6,515	6,216
Chicago & Erie R. R.	2,825	2,684
Chicago & North Western Ry.	113,914	110,184
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	28,377	27,277
Chicago, Burlington & Quincy R. R.	31,226	30,195
Chicago Great Western R. R.	4,409	4,268
Chicago, Indiana & Southern R. R.	2,237	2,131
Chicago, Indianapolis & Louisville Ry.	3,768	3,612
Chicago Junction Ry.	14,076	13,639
Chicago, Milwaukee & St. Paul Ry.	33,574	32,281
Chicago River & Indiana R. R.*	......	......
Chicago, Rock Island & Pacific Ry.	32,486	31,527
Chicago Short Line Ry.	673	652
Chicago Union Transfer Ry.†	......	......
Chicago, West Pullman & Southern R. R.	2,531	2,463
Elgin, Joliet & Eastern Ry.	11,428	11,026
Grand Trunk Western Ry.	5,728	5,504
Illinois Central R. R.	67,962	66,050
Illinois Northern Ry.	1,840	1,795
Indiana Harbor Belt R. R.	3,072	2,929
Lake Shore & Michigan Southern Ry.	29,436	28,287
Michigan Central R. R.	9,152	8,771
Minneapolis, St. Paul & Sault Ste. Marie Ry.	3,256	3,161
New York, Chicago & St. Louis R. R.	5,623	5,407
Pere Marquette R. R.	4,046	3,874
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	14,621	14,087
Pittsburgh, Fort Wayne & Chicago Ry.	26,149	25,118
Pullman R. R.	1,558	1,518
Wabash R. R.	9,862	9,459
Totals	$502,725	$485,343

* Included in the estimates for the Chicago Junction Railway.
† Included in the estimates for the Chicago & Western Indiana Railroad.

CCCXIX, merely represents the share of the several roads in the cost of the spare parts required for the joint operation of all roads as defined (chapter 212). If, in the actual development of electrification, individual roads should prefer to provide and operate individual power stations, substations, contact systems and transmission lines, the costs of spare parts would be in excess of those set forth.

ALTERATIONS TO BRIDGES AND BUILDINGS

213.073 General Considerations: Incident to the execution of any plan of electrifying the railroad terminals of Chicago through the use of an overhead contact system, certain definite and important changes in existing facilities and permanent way structures will be required. Included among these will be changes to buildings, bridges and other structures to provide the minimum clearance specified, changes in existing cross and parallel wire lines (sections 213.076 to 213.080, inclusive), and changes in signal systems (sections 213.081 to 213.088, inclusive). The necessity for these changes has been elsewhere discussed (chapter 208).

In the overhead contact systems of electrification which have served as a basis for the Committee's estimates of cost, electric current is conveyed to the motors of the locomotives or motor cars by the contact of a collector (pantograph) with an electrically energized wire or wires stretched above the track and held in fixed position at proper height by means of suitable supports (section 207.18). The overhead clearance must be adequate not only to permit the passage of the locomotives and cars, but also to provide sufficient room above these for the collecting device, for the contact wire and for the devices which must be employed to secure and to insulate the contact wire. These conditions fix the minimum clearance. In the operation of freight equipment it is desirable to have a greater overhead clearance than that necessary to meet the minimum requirements, in order that trainmen may, when occasion arises, have safe access to the tops of cars.

The plans upon which the Committee's estimates of the cost of electrifying the Chicago terminals are based provide for a minimum clearance of 16 feet, 6 inches, between the top of rail and all overhead structures.* In all cases in which the existing clearance is more than this amount, it has been assumed that there is sufficient space to permit the installation of the contact wires with their supporting insulators and that no alterations to such structures will be required. In cases in which the present clearance is less than 16 feet, 6 inches, the estimates provide for the cost of raising or otherwise altering the structure in question in such manner as may be necessary to provide the required minimum clearance.

Information regarding the present clearance of bridges and other overhead structures was furnished by the railroads (chapter 201). Facts thus obtained were supplemented by additional information obtained by direct inquiry regarding individual structures and by inspection.

213.074 Extent and Costs of the Work Involved in Securing the Required Minimum Clearance under Overhead Structures: In cases

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* This is the minimum clearance recommended by the American Railway Association.

in which the present distance between the top of rail and an overhead structure is less than the minimum required for electric operation with an overhead contact, the additional clearance necessary must be obtained either by raising the overhead structure or by depressing the tracks, and sometimes by a combination of these two methods.

A total of 70 overhead structures within the proposed limits of electrification must be modified to provide the necessary clearance. The work to be done has been determined for each particular structure.

In estimating the costs involved in raising viaducts or other overhead structures, the expense of the following items has been considered:

1. Raising spans over tracks.
2. Raising approach spans where necessary.
3. Providing new bases for support of spans, or building up piers and abutments on which they are supported.
4. Raising street approaches, making necessary fill, and replacing pavements and street car tracks.
5. Providing for wires, cables and pipes of all kinds attached to overhead structures.

In estimating the cost of depressing tracks the expense of the following items has been considered:

1. Lowering tracks under overhead structure.
2. Readjusting approaches at maximum allowable gradient.
3. Replacing ballast and re-surfacing tracks.
4. Putting in a certain proportion of new ties.
5. Lowering sewers, conduits or other openings which are at insufficient depth beneath the tracks.
6. Providing for gas, water and other pipes.
7. Providing new catch-basins and manholes.
8. Changing platforms and team driveways adjacent to tracks.

In order to arrive at the costs of obtaining the necessary clearance under all overhead structures involved within the proposed limits of electrification, the Committee submitted to all of the railroads concerned a complete list of structures on their lines having a clearance of less than 16 feet, 6 inches, with the request that they return, if possible, a definite estimate of the cost of securing the required clearance in each case. Estimates of cost supplied by the railroads were carefully revised by the Committee's structural engineer, and any points of difference were made the subject of conferences between representatives of the Committee and the railroad concerned. Where no information could be obtained directly from the railroads, estimates of cost were prepared by the Committee's staff.

The location of each overhead structure, its present clearance, a statement of the work to be done in providing the necessary minimum clearance of 16 feet, 6 inches, and estimates of cost for the twelve railroads involved, are presented in table CCCXX.

A summary, by roads, of the estimated costs as set forth in table CCCXX is presented as table CCCXXI.

TABLE CCCXXI. SUMMARY OF ESTIMATED COSTS OF SECURING MINIMUM CLEARANCE UNDER OVERHEAD STRUCTURES, BY ROADS
(Basis of 1912)

Railroad	Totals
Atchison, Topeka & Santa Fe Ry	$ 12,000
Baltimore & Ohio Chicago Terminal R. R	34,100
Chicago & Alton R. R	9,800
Chicago & North Western Ry	294,000
Chicago & Western Indiana R. R	12,000
Chicago, Burlington & Quincy R. R	20,050
Chicago Junction Ry	27,500
Chicago, Milwaukee & St. Paul Ry	8,680
Grand Trunk Western Ry	1,000
Illinois Central R. R	2,500
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	6,050
Pittsburgh, Fort Wayne & Chicago Ry	83,000
Total	$510,680

213.075 Estimated Total Cost of Securing Minimum Clearance under Overhead Structures: The total cost of securing minimum clearance under overhead structures for the electric operation of the Chicago railroad terminals is based on the cost of labor and materials as determined for the year 1912, extended in a manner normal to these estimates (section 212.09), the factors of extension in this case being as follows:

	PER CENT
1. To cover growth in mileage of railroads from December 31, 1912, to December 31, 1922	12.0
2. Contingencies	20.0
3. Engineering, design, supervision and administration	10.0
4. Interest, insurance and taxes during construction at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

The values thus derived may be accepted as the total cost, on the basis of the requirements of 1922, of securing the necessary minimum clearance under overhead structures. The cost of this work will be the same for either the 2,400-volt direct current system or the 11,000-volt alternating current system. The estimates of cost are presented by roads in table CCCXXII.

TABLE CCCXX. ESTIMATED COSTS OF RAISING STRUCTURES OR DEPRESSING TRACKS TO PROVIDE MINIMUM CLEARANCE FOR OVERHEAD CONTACT SYSTEM, BY ROADS

(Basis of 1912)

Railroad	Location	Kind	Number of Tracks	Present Min. Clearance	Work to be Done	Estimated Cost	Remarks
1	2	3	4	5	6	7	8
Atchison, Topeka & Santa Fe Ry.	12th St.	Viaduct	3	16 ft. 1 in.	Raise viaduct	$ 3,000	G. T. W. tracks alongside
	Clark St.	Viaduct	2	16 ft. 3 in.	Raise viaduct	6,000	C. & W. I. tracks alongside
	18th St.	Viaduct	5	16 ft. 5 in.	Raise viaduct	3,000	
Baltimore & Ohio Chicago Terminal R. R.	Polk St.	Viaduct	12	16 ft. 4 in.	Raise viaduct	1,000	
	Polk and Taylor Sts.	Viaduct	4	15 ft. 5¼ in.	Raise viaduct	5,000	
	Connecting 12th St.	Viaduct	13	15 ft. 9 in.	Raise viaduct	13,000	
	Canal St.	Viaduct	2	15 ft. 9½ in.	Raise viaduct	15,000	C. B. & Q. and C. & N. W. tracks alongside
	I. H. B. R. R.	Railroad	2	16 ft. 2 in.	Depress track	50	P. C. C. & St. L. tracks alongside
	G. T. W. Ry.	Railroad	2	16 ft. 2 in.	Depress track	50	P. C. C. & St. L. tracks alongside
Chicago & Alton R. R.	Harrison St.	Viaduct	17	15 ft. 6 in.	Raise viaduct and depress tracks	9,000	4 tracks jointly with P. Ft. W. & C. included
	Polk St.	Viaduct	2	15 ft. 8½ in.	Depress tracks	800	C. B. & Q. tracks and 4 joint tracks with P. Ft. W. & C. alongside
Chicago & North Western Ry.	Chicago & Oak Pk. "L"	Railroad	3	16 ft. 1¼ in.	Raise elevated structure	5,000	P. C. C. & St. L. tracks alongside
	Met. "L"	Railroad	1	16 ft. 3¾ in.	Depress tracks	1,000	P. C. C. & St. L. tracks alongside
	Canal St.	Viaduct	3	15 ft. 9¼ in.	Depress tracks	5,000	C. B. & Q. and B. & O. C. T. tracks alongside
	N. State St.	Viaduct	11	14 ft. 10½ in.	Depress tracks	120,000	
	N. Dearborn St.	Viaduct	6	15 ft. 3¼ in.	Depress tracks		
	N. Clark St.	Viaduct	6	14 ft. 9¾ in.	Depress tracks		
	Wells St.	Viaduct	3	15 ft. 5¼ in.	Depress tracks		
	Desplaines St.	Viaduct	1	16 ft. 0 in.	Depress tracks	2,000	C. M. & St. P. and P. C. C. & St. L. alongside
	Halsted St.	Viaduct	7	15 ft. 5¼ in.	Depress tracks	4,000	C. M. & St. P. and P. C. C. & St. L. alongside
	Sangamon St.	Viaduct	2	15 ft. 11½ in.	Raise viaduct	6,000	C. M. & St. P. and P. C. C. & St. L. alongside
	Grand Ave.	Viaduct	9	15 ft. 5½ in.	Raise viaduct	20,000	
	Erie St.	Viaduct	22	15 ft. 5½ in.	Raise viaduct	5,000	
	Chicago Ave.	Viaduct	5	16 ft. ½ in.	Depress tracks	1,000	
	Madison St. Terminal	Train shed	16	15 ft. 4 in.	Revise steel work	125,000	
Chicago & Western Indiana R. R.	Clark St.	Viaduct	4	16 ft. 2 in.	Raise viaduct	11,500	A. T. & S. F. tracks alongside
	St. Charles Air Line	Railroad	4	16 ft. 5 in.	Depress tracks	250	
	L. S. & M. S. Ry.	Railroad	4	16 ft. 4 in.	Depress tracks	250	
Chicago, Burlington & Quincy R. R.	Polk St.	Viaduct	8	15 ft. 2½ in.	Depress tracks	7,000	C. & A. and P. Ft. W. & C. joint tracks
	Taylor St.	Viaduct	7	15 ft. 4½ in.	Depress tracks	7,000	C. & A. and P. Ft. W. & C. joint tracks
	12th St.	Viaduct	5	15 ft. 2½ in.	Depress tracks	5,000	
	Canal St.	Viaduct		15 ft. 7 in.	Depress tracks	1,050	B. & O. C. T. and C. & N. W. tracks alongside
Chicago Junction Ry.	Goldman Mfg. Co.	Canopy	1	16 ft. 0 in.	Depress tracks	125	
	American Can Co.	Foot bridge	1	15 ft. 2 in.	Depress tracks	500	
	Wabash Ave. & 40th St.	Canopy	1	15 ft. 3 in.	Raise canopy	75	
	Wabash Ave. & 40th St.	Foot bridge	1	16 ft. 1 in.	Raise bridge	25	
	Wabash Ave. & 40th St.	Canopy	1	15 ft. 9 in.	Raise canopy	75	
	H. W. Caldwell Son & Co.	Door	1	15 ft. 7½ in.	Door	250	
	Simonds Mfg. Co.	Foot bridge	1	16 ft. 4 in.	Remove bridge	125	
	Simonds Mfg. Co.	Foot bridge	1	15 ft. 9½ in.	Remove bridge	125	
	Sulzberger Sons	Cattle chute	1	14 ft. 0 in.	Raise chute	5,000	
	National Box Co.	Foot bridge	1	16 ft. 4 in.	Raise bridge	350	
	National Box Co.	Canopy	1	15 ft. 7 in.	Raise canopy		
	Manhattan Brew'g. Co.	Canopy	1	16 ft. 5 in.	Raise canopy	50	
	South Side "L" Lowe St.	Railroad	1	15 ft. 6 in.	Depress track	800	
	South Side "L" Kenwood Team Yard	Railroad	4	14 ft. 1 in.	Raise structure	20,000	
Chicago, Milwaukee & St. Paul Ry.	Lake St.	Viaduct	1	15 ft. 10 in.	Depress tracks	950	P. Ft. W. & C. tracks alongside
	Desplaines St.	Viaduct	8	16 ft. ⅛ in.	Depress tracks	1,475	C. & N. W. and P. C. C. & St. L. alongside
	Halsted St.	Viaduct	10	15 ft. 2 in.	Depress tracks	1,835	C. & N. W. and P. C. C. & St. L. alongside
	Sangamon St.	Viaduct	25	15 ft. 10 in.	Depress tracks	4,420	C. & N. W. and P. C. C. & St. L. alongside
Grand Trunk Western Ry.	12th St.	Viaduct	3	16 ft. 5 in.	Depress tracks	1,000	A. T. & S. F. tracks alongside
Illinois Central R. R.	St. Charles Air Line	Railroad	3	16 ft. 4 in.	Remodel floor system	2,500	
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	G. T. W. Ry.	Railroad	2	16 ft. 3 in.	Depress tracks	200	B. & O. C. T. tracks alongside
	I. H. B. R. R.	Railroad	2	16 ft. 3 in.	Depress tracks	200	
	Met. "L"	Railroad	1	16 ft. 2 in.		1,000	C. & N. W. tracks alongside
	Chicago & Oak Pk. "L"	Railroad	2	16 ft. 2 in.	Depress tracks	3,300	C. & N. W. tracks alongside
	Halsted St.	Viaduct	2	15 ft. 10 in.	Depress tracks	550	C. M. & St. P. tracks alongside and 2 tracks jointly with C. M. & St. P.
	Desplaines St.	Viaduct	2	16 ft. 0 in.	Depress tracks	400	C. M. & St. P. and C. & N. W. tracks alongside and 2 tracks jointly with C. M. & St. P.
	Milwaukee Ave.	Viaduct	4	16 ft. 0 in.	Depress tracks	400	C. M. & St. P. tracks and C. & N. W. tracks alongside and 2 tracks jointly with C. M. & St. P.
Pittsburgh, Ft. Wayne & Chicago Ry.	18th St.	Viaduct	10	15 ft. 10 in.	Depress tracks	11,000	2 tracks jointly with C. & A.
	12th St.	Viaduct	5	15 ft. 10 in.	Depress tracks	5,000	C. B. & Q. tracks alongside, 5 tracks jointly with C. & A.
	Taylor St.	Viaduct	5	15 ft. 10 in.	Depress tracks	5,500	C. B. & Q. tracks alongside, 5 tracks jointly with C. & A.
	Polk St.	Viaduct	4	16 ft. 1½ in.	Depress tracks	7,000	C. B. & Q. and C. & A. tracks alongside, 5 tracks jointly with C. & A.
	Van Buren St.	Viaduct	4	15 ft. 8 in.	Depress tracks	5,000	Union Depot tracks included
	Jackson Blvd.	Viaduct	17	14 ft. 7 in.	Depress tracks	24,000	Union Depot tracks included
	Adams St.	Viaduct	4	15 ft. 8 in.	Depress tracks	5,000	Union Depot tracks included
	Madison St.	Viaduct	5	16 ft. 0 in.	Depress tracks	5,000	Union Depot tracks included
	Washington St.	Viaduct	6	16 ft. 0 in.	Depress tracks	5,000	4 tracks jointly with C. M. & St. P.
	Randolph St.	Viaduct	5	16 ft. 0 in.	Depress tracks	5,000	2 tracks jointly with C. M. & St. P.
	Lake St.	Viaduct	6	16 ft. 0 in.	Depress tracks	5,500	C. M. & St. P. tracks alongside, 5 tracks jointly with C. M. & St. P.

TABLE CCCXXII. ESTIMATED TOTAL COST OF SECURING MINIMUM CLEARANCE UNDER OVERHEAD STRUCTURES, BY ROADS*
(Dec. 31, 1922)

Railroad	Total Cost
Atchison, Topeka & Santa Fe Ry	$ 19,604
Baltimore & Ohio R. R.	0
Baltimore & Ohio Chicago Terminal R. R.	55,706
Calumet, Hammond & Southeastern R. R.	0
Chesapeake & Ohio Ry. of Indiana	0
Chicago & Alton R. R.	16,009
Chicago & Calumet River R. R.	0
Chicago & Eastern Illinois R. R.	0
Chicago & Erie R. R.	0
Chicago & North Western Ry	480,288
Chicago & Western Indiana R.R. and the Belt Ry. of Chicago	19,604
Chicago, Burlington & Quincy R. R.	32,754
Chicago Great Western R. R.	0
Chicago, Indiana & Southern R. R.	0
Chicago, Indianapolis & Louisville Ry.	0
Chicago Junction Ry.	44,925
Chicago, Milwaukee & St. Paul Ry	14,180
Chicago River & Indiana R. R.	0
Chicago, Rock Island & Pacific Ry.	0
Chicago Short Line Ry	0
Chicago Union Transfer Ry.	0
Chicago, West Pullman & Southern R. R.	0
Elgin, Joliet & Eastern Ry.	0
Grand Trunk Western Ry	1,633
Illinois Central R. R.	4,084
Illinois Northern Ry	0
Indiana Harbor Belt R. R.	0
Lake Shore & Michigan Southern R. R	0
Michigan Central R. R.	0
Minneapolis, St. Paul & Sault Ste. Marie Ry	0
New York, Chicago & St. Louis R. R.	0
Pere Marquette R. R	0
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	9,883
Pittsburgh, Fort Wayne & Chicago Ry	135,591
Pullman R. R.	0
Wabash R. R	0
Totals	$834,261

* Those roads for which no cost is given reported no obstructions having less than minimum clearance. It is known that there are industrial tracks adjacent to some of these which have such obstructions though not reported to the Committee.

CHANGES IN WIRE LINES

213.076 General Considerations: It has been assumed that all existing wires and cables which cross above tracks, or which parallel tracks in such a manner as to present or threaten physical interference with the contact system or transmission lines, are to be removed or so rearranged as to correct the interference. These include wires which, owing to their location, might cause interference if broken or otherwise deranged. In so far as interference from foreign wires is concerned, the transmission lines and overhead contact construction designed for the alternating current system will be affected in the same manner as those designed for the direct current system, and the changes necessary in foreign wires with the resulting cost will be identical for both systems.

Information regarding the location and character of transverse and parallel wires which are sufficiently near to cause interference was furnished by the railroads on forms prepared by the Committee. This information was supplemented by details obtained from the Western Union Telegraph Company, Postal Telegraph Company, Chicago Telephone Company, Commonwealth Edison Company and the Sanitary District of Chicago. Inspection trips were also made to secure additional facts where required.

213.077 Cross Wires: Examination of the information obtained as above led to the following classification of wires crossing tracks:

1. Telephone wires (open and in cables):
    a. Toll (outside city limits).
    b. Exchange (within city limits).
2. Telegraph wires (open and in cables).
3. Light and power wires:
    a. Of 440 volts or less.
    b. From 440 volts to 11,000 volts.
    c. Of 11,000 volts or more.
4. Special wires,—including signal, street railway feeder and arc light wires.

It was found that most of these wires, as installed at present, would present physical interference with the overhead contact and transmission systems as planned. While it would be possible in many cases to correct this interference by raising the wires, such change would not entirely eliminate all risk of trouble arising from broken wires which might fall and make contact with the wires of the transmission lines and contact system. The estimates have, therefore, been based upon a plan for placing underground all cross wires except those carrying 11,000 volts or more.

Designs of underground crossings were prepared to serve as a basis for the estimates of cost. These follow the present practice of local companies for similar work. They contemplate the use of the poles now supporting the span for terminal poles. These poles are to be guyed and reinforced when necessary, and the additional fixtures required to dead-end the crossing are to be provided. Terminal boxes, potheads and protecting devices are to be installed as needed. The present cables or wires are to be replaced by cables or wires of a suitable kind and placed underground in galvanized iron conduits. The conduits are to extend up the terminal poles a sufficient distance to protect the cables or wires. Where a number of conduits are required to accommodate the wires or cables in service at a crossing, the estimates usually have included the cost of providing a spare or an additional conduit, and for telephone and telegraph crossings the estimates provide for cables having about 25 per cent more wires than those now in use.

Telephone wires at crossings are to be installed in accordance with the standard type of crossings used by the Chicago Telephone Company at boulevards and streets in the residential districts. The present toll line cable crossings are to be changed to underground crossings using 53-pair cables. Toll line open wire crossings are to be changed to underground crossings using 23-pair, 37-pair or 53-pair cables as required. The present exchange line cable crossings are to be changed to underground crossings using 50-pair cables. Exchange line open wire crossings are to be changed to underground crossings using 25-pair, 30-pair or 50-pair cables.

The designs for underground telegraph crossings were made after consultation with representatives of the telegraph companies. The present telegraph cable crossings are to be changed to underground crossings using 50-pair cables. Open wire telegraph crossings are to be changed to underground crossings using 5-pair, 10-pair, 15-pair, 25-pair or 37-pair cables as required.

Light and power underground crossing designs are in accordance with the practice of the Commonwealth Edison Company. Crossings of wires carrying 440 volts or less are to be made with rubber covered wire pulled through the conduits. Crossing lines carrying 440 to 11,000 volts are to be installed underground with single conductor lead covered cables insulated for the voltage carried. Crossing wires of voltages higher than 11,000 are not to be placed underground but are to be raised and installed in accordance with the specifications for overhead crossings of electric light and power lines of the American Railway Engineering Association. The estimates were based on a design of a standard crossing which would be applicable to any case. The design provides for two steel transmission towers 65 feet in height supporting a 150-foot crossing span of nine No. 0 A. W. G. copper wires equivalent to the average of such crossings. The towers are designed to withstand the unbalanced load of 5,000 pounds which would occur were three of the nine wires broken. Strain insulators are to be used for dead-ending the wires.

Special wire crossings include those for signal wires, arc light circuits of 4,000 and 9,000 volts, 600-volt railway feeders and combinations of some of these. Signal wire crossings are to be placed underground, using cables of 3, 4, 5, 6, 12 or 19 wires as required. Single conductor lead covered cable is to be used in the underground crossings of arc light circuits. Railway feeders of 600 volts are to be installed underground in lead covered rubber insulated single conductor cables. The necessary modifications to 600-volt trolley wires crossing tracks have been referred to in section 213.026, and their cost has been included as part of the cost of the contact system. Estimates to meet the peculiar conditions of other special wire crossings covered by this classification were made.

213.078 Parallel Wires: From the information obtained it has been possible to determine the character and location of all wires adjacent and parallel to the tracks to be electrified. In general, the same classes of wire are to be found paralleling tracks as have been hereinbefore classified as crossing tracks. Examination of the information was made, by roads and by route elements (chapter 104), to determine what wires would interfere with the erection of the contact system and transmission lines or, by falling, would endanger them. The ultimate requirement in this respect demands that no wire be allowed to remain in position where, if its supporting pole were broken at the ground surface, it would not, when falling towards the track, clear the contact and transmission wires by three feet. If the width of the right-of-way permits, the line is to be moved to a safe distance from the tracks; if there is not sufficient space on the right-of-way for this, the line may be rebuilt in the adjacent streets, replaced by cables supported on the steel structures of the contact system, or placed underground in conduits. At places where sidings or spur tracks leave the main tracks, the wires paralleling the main track now usually cross over the spur. At such places the estimates provide for replacing these wires by cables in underground conduits.

Changes to lines which would result in open wire construction involve building a new pole line and moving the old wire to the new poles or providing new wire. Where the change would require cable construction, the estimates allow for cables having about 25 per cent more conductors than are installed in the present open wire construction. In a few instances telephone and telegraph circuits are to be installed in a single cable, but separate cables are always to be furnished for signal circuits.

Open wire lines have been considered preferable to cables, and estimates have been based upon the use of this type of construction where conditions permit, but only 42 per cent of the mileage of parallel lines requiring changes will remain as open wire line. The total length of parallel lines to be changed amounts to 197.16 miles. Of this, 83.30 miles of line will be open wire construction, 108.50 miles of line will be aërial cable construction, 2.25 miles of line will be underground construction and 2.84 miles of line will be underground spur track crossings.

213.079 Estimates of Costs of Changes in Wire Lines on the Basis of the Requirements of 1912, Excluding all Allowances for Contingencies and for Engineering: Estimates of costs of each of the standard designs of crossings were made and plotted in terms of length of underground line, and the values taken from these diagrams were applied to the individual crossings. The same general method was used to obtain the cost of changes in parallel lines. A list was made of the number and character of the changes required, and the costs of standard designs were plotted in terms of length of line to be changed. Salvage was allowed on replaced lines, equal to 60 per cent of cost of line when new, less the cost of labor required to remove it.

In cases where the wires cross the tracks of more than one railroad, the cost of the change is distributed among the railroads in proportion to the number of tracks crossed. The cost of changing wires which are parallel to sections of right-of-way where joint contact system structures spanning the tracks of more than one railroad are to be provided, has been divided equally among the railroads owning the tracks. As stated elsewhere (section 212.14), no attempt has been made in this case to fix the responsibility for the cost of the changes to wires, all costs being charged to the railroads regardless of the ownership of the wires. The extent to which the different classes of wire are involved is as follows:

	PER CENT
Telephone wires	31.0
Telegraph wires	33.8
Light and power wires	33.2
Special wires	2.0

The costs of the changes and alterations to wires which cross or parallel tracks, estimated in the manner described and excluding all allowances for contingencies and for engineering, are common to both the 2,400-volt direct current system and the 11,000-volt alternating current system. These estimates are set forth in table CCCXXIII.

TABLE CCCXXIII. ESTIMATED COSTS OF CHANGES TO TRANSVERSE AND PARALLEL WIRES, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING, BY ROADS
(Basis of 1912)

Railroad	Cross Wires	Parallel Wires	Total Cost
1	2	3	4
Atchison, Topeka & Santa Fe Ry.	$ 43,221	$ 7,032	$ 50,253
Baltimore & Ohio R. R.	11,267	7,229	18,496
Baltimore & Ohio Chicago Terminal R. R.	39,460	17,046	56,506
Calumet, Hammond & Southeastern R. R.	2,130	315	2,445
Chesapeake & Ohio Ry. of Indiana	0	0	0
Chicago & Alton R. R.	18,150	5,517	23,667
Chicago & Calumet River R. R.	0	0	0
Chicago & Eastern Illinois R. R.	2,027	0	2,027
Chicago & Erie R. R.	7,610	1,047	8,657
Chicago & North Western Ry.	205,077	35,995	241,072
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	82,729	46,168	128,897
Chicago, Burlington & Quincy R. R.	26,554	24,779	51,333
Chicago Great Western R. R.	0	0	0
Chicago, Indiana & Southern R. R.	12,918	855	13,773
Chicago, Indianapolis & Louisville Ry.	9,851	1,620	11,471
Chicago Junction Ry.	16,897	16,511	33,408
Chicago, Milwaukee & St. Paul Ry.	58,501	19,972	78,473
Chicago River & Indiana R. R.	0	0	0
Chicago, Rock Island & Pacific Ry.	66,856	16,730	83,586
Chicago Short Line Ry.	0	0	0
Chicago Union Transfer Ry.	1,602	0	1,602
Chicago, West Pullman & Southern R. R.	0	0	0
Elgin, Joliet & Eastern Ry.	2,911	1,396	4,307
Grand Trunk Western Ry.	12,438	2,283	14,721
Illinois Central R. R.	112,081	28,670	140,751
Illinois Northern Ry.	680	0	680
Indiana Harbor Belt R. R.	7,557	505	8,062
Lake Shore & Michigan Southern Ry.	26,529	28,873	55,402
Michigan Central R. R.	17,398	4,954	22,352
Minneapolis, St. Paul & Sault Ste. Marie Ry.	0	0	0
New York, Chicago & St. Louis R. R.	18,837	11,191	30,028
Pere Marquette R. R.	0	345	345
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	40,309	15,882	56,191
Pittsburgh, Fort Wayne & Chicago Ry.	53,021	24,506	77,527
Pullman R. R.	9,680	3,136	12,816
Wabash R. R.	11,060	1,502	12,562
Totals	$917,351	$324,059	$1,241,210

213.080 Estimated Total Cost of Changes to Transverse and Parallel Wires: The total cost of the changes and alterations to both cross and parallel wires, necessary under electric operation of the Chicago terminals, is based upon the cost of labor and materials as determined for 1912, extended in a manner normal to these estimates (chapter 212), the factors of extension in this case being as follows:

	PER CENT
1. To cover growth in mileage of railroads and extent of wires, at 3.0 per cent per annum for 4 years, December 31, 1912, to December 31, 1916 . . .	12.0
2. Contingencies	20.0
3. Engineering, design, supervision and administration	10.0
4. Interest, insurance and taxes during construction, at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

The estimated total cost, by railroads, of all changes and alterations necessary to wire lines is set forth by table CCCXXIV.

TABLE CCCXXIV. ESTIMATED TOTAL COST OF ALL CHANGES TO WIRE LINES, BOTH CROSS AND PARALLEL
(Dec. 31, 1922)

Railroad	Total Cost
Atchison, Topeka & Santa Fe Ry	$ 82,095
Baltimore & Ohio R. R	30,216
Baltimore & Ohio Chicago Terminal R. R	92,310
Calumet, Hammond & Southeastern R. R	3,995
Chesapeake & Ohio Ry. of Indiana	0
Chicago & Alton R. R	38,663
Chicago & Calumet River R. R	0
Chicago & Eastern Illinois R. R	3,311
Chicago & Erie R. R	14,143
Chicago & North Western Ry	393,823
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	210,571
Chicago, Burlington & Quincy R. R	83,859
Chicago Great Western R. R	0
Chicago, Indiana & Southern R. R	22,500
Chicago, Indianapolis & Louisville Ry	18,740
Chicago Junction Ry	54,576
Chicago, Milwaukee & St. Paul Ry	128,196
Chicago River & Indiana R. R	0
Chicago, Rock Island & Pacific Ry	136,548
Chicago Short Line Ry	0
Chicago Union Transfer Ry	2,617
Chicago, West Pullman & Southern R. R	0
Elgin, Joliet & Eastern Ry	7,036
Grand Trunk Western Ry	24,050
Illinois Central R. R	229,935
Illinois Northern Ry	1,111
Indiana Harbor Belt R. R	13,170
Lake Shore & Michigan Southern Ry	90,506
Michigan Central R. R	36,515
Minneapolis, St. Paul & Sault Ste. Marie Ry*	......
New York, Chicago & St. Louis Ry	49,054
Pere Marquette R. R	563
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	91,796
Pittsburgh, Fort Wayne & Chicago Ry	126,651
Pullman Railroad	20,936
Wabash Railroad	20,521
Total	$2,028,007

* Owns no track to be electrified.

CHANGES IN SIGNAL SYSTEMS

213.081 Necessity for Changes: The electrification of Chicago's railroad terminals will necessitate changes in certain portions of existing block and switch signaling apparatus. These changes will involve both the signal structures and the means employed in the control and operation of the signals. Many of the signal structures are so designed and located with reference to the running tracks as to encroach upon the clearances which must be allowed for electric operation. In such cases changes must be made to provide for the required clearances. All automatically controlled signals employ the running rails of the track to form a part of an electric circuit by which their action is controlled. With the introduction of electric operation of trains, the running rails of the track must also carry the return traction current, the presence of which would make inoperative the existing signal track circuits. It is required, therefore, that the signal track circuits be modified in such manner that their operation will not be affected by the presence of the traction current.

It was first determined by the Committee which of the 37 roads to be electrified had signal track circuits in operation. A canvass of the local offices of these roads was made. Copies of plans showing lay-out of signals and notes relative to the types and modes of operation were obtained. Where reports proved to be insufficient, inspections of individual roads or of individual signal installations were made.

213.082 Existing Signals: Block signals are those having fixed locations and controlling the use of a definite stretch of track. They may be classified as to the manner in which their indications are displayed, as follows:

1. Banner signals, the day indication being displayed by a revolving banner.
2. Disk signals, the day indication being displayed by a movement of a disk in front of a fixed background.
3. Semaphore signals, the day indication being displayed by the position of an arm moving in a vertical plane at right angles to the track.
4. Light signals, the day indication being displayed by lights behind lenses of different colors.

Night indications for all of these signals are displayed by lights.

Signals may be classified with reference to the manner in which they are controlled and operated, as follows:

1. Manual signals, controlled and operated by hand.
2. Controlled manual signals, operated manually but requiring co-operation between the various operators.
3. Automatic signals, controlled by the train and operated by power which may be either electricity, compressed air or compressed gas.
4. Semi-automatic signals, partially controlled by the train and partially by an operator with lever action, the actual operation being secured by power as in the case of the automatic signal.

All of these types of signals are to be found in the Chicago terminals. Some of them have been long in service while others are of modern design and of recent installation. They serve to indicate the position of a track switch, to give control of a railroad crossing or to admit or exclude trains from certain sections, or blocks, of track. In addition to these indicating devices, there are many "interlocking plants" from which signals are controlled and switches are thrown. The locations of the interlocking plants within the Area of Investigation are shown by fig. 649.

The extent of the interlocking and signal installations within the Area of Investigation is suggested by the following enumeration:

Number of interlocking plants	133
Total number of levers	7,163
Number of automatic block signals	1,245
Equivalent miles of single track equipped with automatic signals	802

213.083 Imperative Changes: The imperative physical changes necessitated by electrification will vary with the traction system adopted. In case the overhead contact system is employed, it has been assumed that existing signal bridges will, where necessary, be raised to give the required overhead clearance; that they will be used to support the contact wires; and that the signals and their connections will be rearranged to permit these changes. All of these physical changes have been analyzed in connection with the design of contact systems (section 213.025), and estimates of cost covering this portion of the signal work are included with the estimates of the cost of the contact system.

The functional changes involved are more complex. Many of the present signals to be dealt with are controlled by electric track circuits, the action being such that the signals assume their position automatically when a train enters the block governed by them. The track circuits at present employed in Chicago are mainly of the low voltage direct current type, which would be affected by stray traction currents either of the direct or of the alternating current type in the rails. The introduction of electric traction therefore requires the use of alternating current track circuits for switch and signal control. The currents of these circuits flow in the track rails simultaneously with the more powerful currents of the traction system, but they are of a different character and operate upon relays capable of selecting between the signaling current and the propulsion current. Where direct current for traction is used, the relay may be rendered selective by being designed to operate on the inductive principle so applied that it will close its contacts on alternating current but not on direct current. Where alternating current is used for traction, the relay is made to work selectively on the basis of its alternations; for example, with a 25-cycle alternating current traction system the signal current frequency is generally 60 cycles and the signal relay is designed to respond to the 60-cycle current but not to the 25-cycle current.

The traffic to be handled electrically is heavy and the traction current required will be correspondingly large. Under these conditions it will be necessary to use both rails for the return circuit. Both rails also are to be used to carry simultaneously the current controlling signals. The signal circuits, however, deal with definite lengths of track. The integrity of the signal track circuits is preserved by isolating them one from another by means of insulated rail joints, so that a definite length of track may constitute the circuit which controls each individual signal or series of signals. The traction current, on the other hand, must flow without interruption along the track from signal track circuit to signal track circuit back to the power house or to the substation, and the signal track circuits must offer no hindrance to such flow. These functions are secured by the use of an impedance bond which permits the track circuits to be connected one with another for traction current but to remain isolated for signal current.

The changes in signals, therefore, for which provision must be made, include the adaptation of existing signal systems within the proposed limits of electrification to the use of alternating current (preferably 60-cycle) track circuits. This change involves elements for each track circuit, as follows:

1. The generators for the control current.
2. The alternating current track relay.
3. A small track transformer for feeding the track relay through the rails.
4. An impedance bond to perform functions already described.

FIG. 649. LOCATIONS OF INTERLOCKING PLANTS IN THE AREA OF INVESTIGATION

213.084 Optional Changes in Signals: The functional changes outlined in the preceding section are, as has been stated, necessary for all signal and switch installations employing electric track circuit control. In addition, there are certain functional changes in such systems which, if made, would affect only the economy of installation or of operation, and which, for present purposes, are regarded as optional. The estimates of cost hereinafter presented do not include them. For example, the usual gravity primary battery, characteristic of the low voltage direct current signal track circuits now used, cannot serve in supplying alternating current track circuits which, under the rearrangement, must be provided, and might therefore be omitted were it not for the fact that practically all of the automatic signals in the Chicago terminals are electrically operated as well as electrically controlled, and that they employ for their operation the same primary batteries now used for the track circuits. Since it is essential to substitute a centralized alternating current supply for the track circuits, it would mean greater operating economy to employ the same form of power for operating the signals. Such a change would, however, necessitate detailed changes in the mechanism of the signals themselves, the extent and cost of which would be materially affected by the character of the existing signal installation.

It is obvious that in the working out of this problem many optional changes would be made; old devices, instead of being changed, would be replaced by more modern installations, and signal equipment covering limited trackage would, in the face of extensive changes, be more or less extended so that the efficiency of the whole installation might be increased. As already indicated, the estimates of cost are not designed to cover any such changes or extensions.

213.085 Transmission and Power Systems: The alternating current signal track circuit is most economically supplied from a central power source from which it may be distributed to local substations along the line of the track by means of a transmission system. This system may involve overhead wires attached to the traction contact structures and to poles, or it may be in the form of underground cables. The overhead wires represent the least costly method and constitute the basis of the estimates of cost which are hereinafter presented. It is assumed that all transmission lines will be of duplicate circuits.

As the traction current has electrical characteristics different from the current used for the signal track circuits, and as it is desirable for each road to have its own signal power system, the estimates provide for one or more signal power substations for each railroad. In these substations, a traction current at high voltage is passed through transformers and frequency changing sets, which serve to deliver power to the local signal transmission lines at 60 cycles and at the usual potential of 2,200 volts. It is assumed for the purpose of these estimates that these signal substations, where possible, are to be located in existing buildings or in the traction substations in order to minimize their cost. In each substation the frequency changing sets are assumed to be installed in duplicate, together with other apparatus such as switchboards, lightning arresters, transformers and regulating instruments. The estimates are designed to cover only such apparatus as is required to provide for the signals at present installed, with the necessary spare apparatus for emergencies.

213.086 Unit Costs: A careful investigation of the factors involved has resulted in the establishment of unit costs covering details of existing signal systems which must be changed to adapt them to the conditions which will be introduced by electric traction. These unit costs are presented in table CCCXXV.

TABLE CCCXXV. UNIT COSTS OF CHANGES IN EXISTING SIGNAL SYSTEMS

(Basis of 1912)

Item 1	2,400-Volt D. C. 2	11,000-Volt A. C. 3
Track circuits	$ 1,400	$ 1,200
Switches within track circuit limits	400	300
Signal transmission line, per mile of duplicate circuit	950	950
Signal power substations, without buildings	11,000	11,000
Signal power substations, with buildings	15,000	15,000
Crossing bells with track circuits	550	550
Additions to interlocking plants for each additional lever	1,000	1,000

213.087 Estimated Costs of Changes in Signals, on the Basis of the Requirements of 1912, Excluding all Allowances for Contingencies and for Engineering: The number of each kind of unit required has been determined for each road involved. By multiplying this number by the

TABLE CCCXXVI. ESTIMATED COSTS OF LABOR AND MATERIAL FOR CHANGES IN SIGNALS, BY ROADS, 2,400-VOLT D. C. SYSTEM

Railroad	Track Circuit Installations		Switches within Track Circuit Limits		Signal Transmission Line		Signal Power Substations		Crossing Bells with Track Circuits		Additions to Interlocking Plants		Total Cost
	No.	Cost	No.	Cost	Miles	Cost	No.	Cost	No.	Cost	No.	Cost	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Baltimore & Ohio R. R.	32	$ 44,800	9	$ 3,600	12.4	$11,780	1	$15,000	.....	....	15	$15,000	$ 90,180
Baltimore & Ohio Chicago Terminal R. R.	63	88,200	73	29,200	36.1	34,295	1	15,000	1	$ 550	5	5,000	172,245
Chicago & Alton R. R.	30	42,000	19	7,600	8.0	7,600	1	15,000	.....	....	.....	....	72,200
Chicago & Eastern Illinois R. R.	12	16,800	6	2,400	3.0	2,850	1	15,000	.....	....	.....	....	37,050
Chicago & North Western Ry.	701	981,400	287	114,800	84.1	79,895	2	26,000	.....	....	.....	....	1,202,095
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	155	217,000	39	15,600	23.5	22,325	1	15,000	.....	....	.....	....	269,925
Chicago, Burlington & Quincy R. R.	73	102,200	18	7,200	7.3	6,935	1	15,000	.....	....	20	20,000	151,335
Chicago, Indiana & Southern R. R.	25	35,000	25	10,000	4.4	4,180	1	15,000	.....	....	3	3,000	67,180
Chicago, Indianapolis & Louisville Ry.	8	11,200	8	3,200	4.4	4,180	1	15,000	.....	....	.....	....	33,580
Chicago, Milwaukee & St. Paul Ry.	120	168,000	49	19,600	18.1	17,195	1	15,000	.....	....	.....	....	219,795
Chicago, Rock Island & Pacific Ry.	91	127,400	51	20,400	15.9	15,105	1	15,000	8	4,400	.....	....	182,305
Illinois Central R. R.	387	541,800	117	46,800	29.0	27,550	1	15,000	.....	....	10	10,000	641,150
Lake Shore & Michigan Southern Ry.	191	267,400	93	37,200	28.1	26,695	1	11,000	.....	....	.....	....	342,295
Michigan Central R. R.	52	72,800	15	6,000	11.3	10,735	1	15,000	.....	....	15	15,000	119,535
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	14	19,600	20	8,000	26.0	24,700	1	15,000	6	3,300	15	15,000	85,600
Pittsburgh, Fort Wayne & Chicago Ry.	119	166,600	67	26,800	31.5	29,925	1	11,000	.....	....	15	15,000	249,325
Totals	2,073	$2,902,200	896	$358,400	343.1	$325,915	17	$213,000	15	$8,250	98	$98,000	$3,935,795
Alterations to Interlocking Only													
Atchison, Topeka & Santa Fe Ry.											15	$15,000	$15,000
Chesapeake & Ohio Ry. of Indiana											10	10,000	10,000
Chicago Great Western R. R.											7	7,000	7,000
Indiana Harbor Belt R. R.											10	10,000	10,000
New York, Chicago & St. Louis R. R.											3	3,000	3,000
Wabash Railroad											15	15,000	15,000
Totals											60	60,000	60,000
Grand Totals											158	$158,000	$3,995,795

TABLE CCCXXVII. ESTIMATED COSTS OF LABOR AND MATERIAL FOR CHANGES IN SIGNALS, BY ROADS, 11,000-VOLT A. C. SYSTEM

Railroad	Track Circuit Installations		Switches within Track Circuit Limits		Signal Transmission Line		Signal Power Substations		Crossing Bells with Track Circuits		Additions to Interlocking Plants		Total Cost
	No.	Cost	No.	Cost	Miles	Cost	No.	Cost	No.	Cost	No.	Cost	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Baltimore & Ohio R. R.	32	$ 38,400	9	$ 2,700	12.4	$11,780	1	$15,000	.....	....	15	$15,000	$ 82,880
Baltimore & Ohio Chicago Terminal R. R.	63	75,600	73	21,900	36.1	34,295	1	15,000	1	$ 550	5	5,000	152,345
Chicago & Alton R. R.	30	36,000	19	5,700	8.0	7,600	1	15,000	.....	....	.....	....	64,300
Chicago & Eastern Illinois R. R.	12	14,400	6	1,800	3.0	2,850	1	15,000	.....	....	.....	....	34,050
Chicago & North Western Ry.	701	841,200	287	86,100	84.1	79,895	2	26,000	.....	....	.....	....	1,033,195
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	155	186,000	39	11,700	23.5	22,325	1	15,000	.....	....	.....	....	235,025
Chicago, Burlington & Quincy R. R.	73	87,600	18	5,400	7.3	6,935	1	15,000	.....	....	20	20,000	134,935
Chicago, Indiana & Southern R. R.	25	30,000	25	7,500	4.4	4,180	1	15,000	.....	....	3	3,000	59,680
Chicago, Indianapolis & Louisville Ry.	8	9,600	8	2,400	4.4	4,180	1	15,000	.....	....	.....	....	31,180
Chicago, Milwaukee & St. Paul Ry.	120	144,000	49	14,700	18.1	17,195	1	15,000	.....	....	.....	....	190,895
Chicago, Rock Island & Pacific Ry.	91	109,200	51	15,300	15.8	15,105	1	15,000	8	4,400	.....	....	159,005
Illinois Central R. R.	387	464,400	117	35,100	29.0	27,550	1	15,000	.....	....	10	10,000	552,050
Lake Shore & Michigan Southern Ry.	191	229,200	93	27,900	28.1	26,695	1	11,000	.....	....	.....	....	294,795
Michigan Central R. R.	52	62,400	15	4,500	11.3	10,735	1	15,000	.....	....	15	15,000	107,635
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	14	16,800	20	6,000	26.0	24,700	1	15,000	6	3,300	15	15,000	80,800
Pittsburgh, Fort Wayne & Chicago Ry.	119	142,800	67	20,100	31.5	29,925	1	11,000	.....	....	15	15,000	218,825
Totals	2,073	$2,487,200	896	$268,800	343.1	$325,945	17	$243,000	15	$8,250	98	$98,000	$3,431,595
Alterations to Interlocking Only													
Atchison, Topeka & Santa Fe Ry.											15	$15,000	$15,000
Chesapeake & Ohio Ry. of Indiana											10	10,000	10,000
Chicago Great Western R. R.											7	7,000	7,000
Indiana Harbor Belt R. R.											10	10,000	10,000
New York, Chicago & St. Louis R. R.											3	3,000	3,000
Wabash Railroad											15	15,000	15,000
Totals											60	60,000	60,000
Grand Totals											158	$158,000	$3,491,595

unit cost, the estimated cost on the basis of the requirements of 1912, excluding all allowances for contingencies and for engineering, has been obtained. These estimates for the 2,400-volt direct current system and for the 11,000-volt alternating current system are set forth by tables CCCXXVI and CCCXXVII, respectively.

213.088 Estimated Total Cost of Changes in Signal Systems: The total cost of changes in signal systems for the electric operation of the Chicago terminals is based on the cost of labor and materials as determined for the year 1912, extended in a manner normal to these estimates (chapter 212), except as to the first factor involved. No logical basis has been developed upon which the rate of growth in the number of signals or in the mileage of track covered by them during the four years subsequent to 1912 can be predicted. It has been shown that the total mileage of track will increase 3 per cent each year. As the signal mileage has in recent years increased much more rapidly than the track mileage, it may be safely assumed that signals will increase at a rate of more than 3 per cent a year, and in the absence of a definite basis it is assumed that this increase will be 5 per cent. The factors of extension in this case are, therefore, as follows:

	PER CENT
1. To cover growth, at 5 per cent per annum for 4 years, December 31, 1912, to December 31, 1916	20.0
2. Contingencies	20.0
3. Engineering, design, supervision and administration	10.0
4. Interest, insurance and taxes during construction, at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

The costs thus derived may be accepted as the estimated total costs of the necessary changes in signals. These costs are given, by railroads, for the 2,400-volt direct current system and the 11,000-volt alternating current system in table CCCXXVIII.

TABLE CCCXXVIII. ESTIMATED TOTAL COST OF CHANGES IN SIGNALS, BY ROADS
(Dec. 31, 1922)

Railroad	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3
Atchison, Topeka & Santa Fe Ry	$ 26,255	$ 26,255
Baltimore & Ohio R. R.	157,844	145,067
Baltimore & Ohio Chicago Terminal R. R.	301,484	266,653
Calumet, Hammond & Southeastern R. R.	0	0
Chesapeake & Ohio Ry. of Indiana	17,503	17,503
Chicago & Alton R. R.	126,373	112,545
Chicago & Calumet River R. R.	0	0
Chicago & Eastern Illinois R. R.	64,849	59,508
Chicago & Erie R. R.	0	0
Chicago & North Western Ry	2,104,051	1,808,422
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	472,455	411,368
Chicago, Burlington & Quincy R. R.	264,885	236,179
Chicago Great Western R. R.	12,252	12,252
Chicago, Indiana & Southern R. R.	117,586	104,459
Chicago, Indianapolis & Louisville Ry	58,776	54,575
Chicago Junction Ry	0	0
Chicago, Milwaukee & St. Paul Ry	384,711	334,128
Chicago River & Indiana R. R.	0	0
Chicago, Rock Island & Pacific Ry	319,092	278,310
Chicago Short Line Ry	0	0
Chicago Union Transfer Ry	0	0
Chicago, West Pullman & Southern R. R.	0	0
Elgin, Joliet & Eastern Ry	0	0
Grand Trunk Western Ry	0	0
Illinois Central R. R.	1,122,218	966,264
Illinois Northern Ry	0	0
Indiana Harbor Belt R. R.	17,503	17,503
Lake Shore & Michigan Southern Ry	599,126	515,985
Michigan Central R. R.	209,224	188,395
Minneapolis, St. Paul & Sault Ste. Marie Ry*	....	....
New York, Chicago & St. Louis R. R.	5,251	5,251
Pere Marquette R. R.	0	0
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	149,827	141,426
Pittsburgh, Fort Wayne & Chicago Ry	436,399	383,014
Pullman Railroad	0	0
Wabash Railroad	26,255	26,255
Totals	$6,993,919	$6,111,407

*Owns no track to be electrified.

REMOVAL AND RE-ESTABLISHMENT OF STEAM LOCOMOTIVE TERMINALS

213.089 Definition of the Work Involved: The electrification of Chicago's railroad terminals and the elimination of the steam locomotive from the city will make possible the removal of all steam locomotive terminals now located within the city, and will require the establishment of new steam locomotive terminals at points beyond the city limits. Under the plans of the Committee, provision will need to be made also at points outside the city for tracks for the change of motive power, and at selected points, within the city in some cases and outside the city in others, for the care and handling of electric locomotives and multiple-unit equipment. In a few cases the facilities which are now in use for steam equipment may be rearranged to accommodate electric equipment.

The various factors involved are herein considered under three divisions:

1. Property in the form of facilities which, in the event of electrification, will be rendered worthless to the railroads and will, under the plan of the Committee, be abandoned.
2. The removal, from present locations within the city to new locations outside the city, of certain machinery.
3. New facilities which in the event of electrification will need to be constructed at points both within and outside of the city.

The loss which will result from the abandonment of certain facilities cannot, under the rulings of the Interstate Commerce Commission, be regarded as chargeable against electrification, but the extent of such loss is set forth as a fact of interest. Under the Committee's accounting statement, section 401.13, the amount involved is regarded as chargeable to operation over a period of ten years from the date of the completion of the electric installation. The cost involved in the removal of machinery from points within the city to points outside of the city, and the cost of the necessary new construction, properly constitute charges against electrification.

As a basis for estimates, a program of procedure has been adopted covering facilities to be abandoned, machinery to be removed to new locations and new facilities to be constructed. For estimating purposes, lists and preliminary plans of tracks and structures have been prepared for each road. Information concerning costs has been derived from many sources.

It should be noted that the facts and estimates which follow relate only to permanent way structures. The problems relating to the disposition of the rolling stock which will be released from the service in which it is now engaged, are discussed elsewhere (sections 213.097 to 213.108).

213.090 Description of Facilities to be Abandoned: Existing facilities which, in the event of electrification, will be rendered worthless to the railroad companies and will normally be dismantled or otherwise disposed of, include:

1. Engine houses.
2. Coaling stations.
3. Cinder pits.
4. Turn-tables.
5. Tanks.
6. Certain tracks.
7. Certain shop machinery.
8. Sand and oil houses.
9. Minor structures.

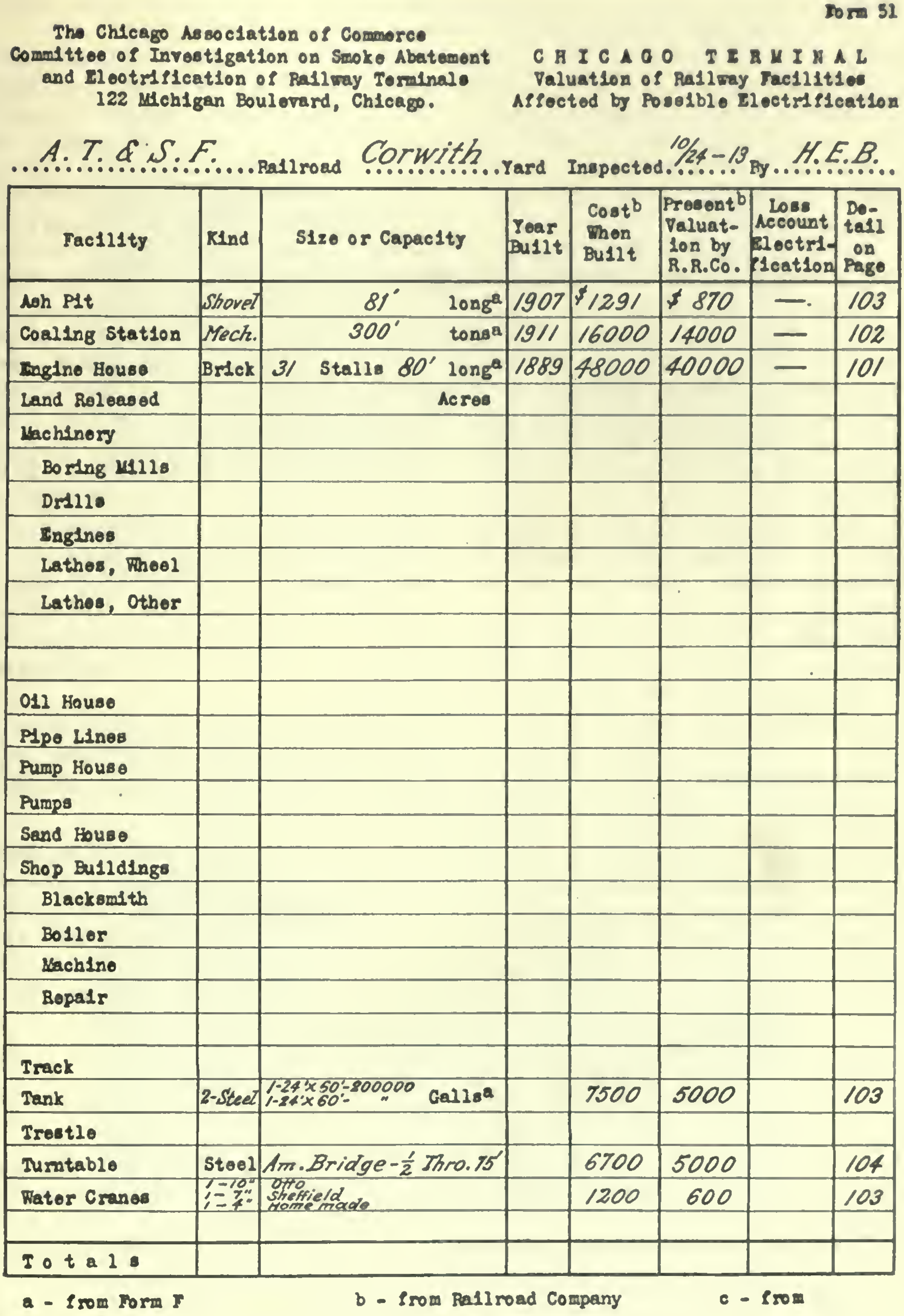
The facilities to be abandoned are located in most cases within the city limits of Chicago. Lists of all such facilities were supplied to each railroad, together with a blank form upon which the first cost, present value and salvage value of each facility might be entered. Responses were made up from the records of the owning companies. The structures involved were then inspected by representatives of the Committee and, in a few cases, the present values as indicated by the records of owning companies were changed to correct obvious errors. A typical railroad report relating to the value of affected facilities is shown by fig. 650.

The possibility of transferring such facilities as coaling stations, turn-tables and water tanks from present locations to new locations has been considered by the Committee, but owing to the requirements of continuous operation during the construction period such procedure has not been regarded as practicable. It is obvious that until the new facilities which are to be constructed at the new motive power terminals at transfer yards are in working order, it will be necessary to retain the existing facilities in their present locations. Only in the case of machinery has it been deemed practicable to provide for removal to new locations. The age and first cost of facilities have been taken as reported by the railroads, their records, which in most cases were found to be comprehensive, being accepted as conclusive.

The term "present value," as employed in this discussion, represents the value of the facility to the railroad company as compared with the cost of a new structure for performing a similar service. The present value is dependent upon the age and condition. Thus, a coaling station which cost $20,000 five years ago and which has been subject to an annual depreciation of 5 per cent, is estimated to have a present value of $15,000. Should the road abandon this facility, the salvage value would depend upon its salability. This fact, however, does not vitiate its present value as indicated, since, as a going facility, it is now serving its purpose and will continue to do so until it is rendered unserviceable by age or other cause.

The present values generally were accepted as reported by the owning companies. In a few instances in which the values reported appeared inaccurate they were corrected on the basis of reported first cost, less the estimated depreciation since the date of construction, the rate of depreciation in each case being dependent upon the type of facility involved. For example, the life of an ash-pit was assumed to vary from seven to ten years, according to its construction and the severity of service conditions.

The salvage values were fixed at amounts representing the fair selling price of the facility in the open market. The rapid depreciation and



Form 51

The Chicago Association of Commerce
Committee of Investigation on Smoke Abatement
and Electrification of Railway Terminals
122 Michigan Boulevard, Chicago.

CHICAGO TERMINAL
Valuation of Railway Facilities
Affected by Possible Electrification

A. T. & S. F. ....Railroad Corwith ....Yard Inspected 10/24-13 By H.E.B.

Facility	Kind	Size or Capacity	Year Built	Cost[b] When Built	Present[b] Valuation by R.R.Co.	Loss Account Electrification	Detail on Page
Ash Pit	Shovel	81' long[a]	1907	$1291	$ 870	—	103
Coaling Station	Mech.	300' tons[a]	1911	16000	14000	—	102
Engine House	Brick	31 Stalls 80' long[a]	1889	48000	40000	—	101
Land Released		Acres					
Machinery							
Boring Mills							
Drills							
Engines							
Lathes, Wheel							
Lathes, Other							
Oil House							
Pipe Lines							
Pump House							
Pumps							
Sand House							
Shop Buildings							
Blacksmith							
Boiler							
Machine							
Repair							
Track							
Tank	2-Steel	1-24'x50'-200000 1-24'x60'- " Galls[a]		7500	5000		103
Trestle							
Turntable	Steel	Am. Bridge-$\frac{1}{2}$ Thro. 75'		6700	5000		104
Water Cranes	1-10" 1-7" 1-4"	Otto Sheffield Home made		1200	600		103
Totals							

a - from Form F b - from Railroad Company c - from

FIG. 650. TYPICAL FORM USED BY RAILROADS IN REPORTING THE VALUE OF ABANDONED PROPERTY ("FORM 51")

the immobility of many railroad facilities have justified the assumption of low salvage values. An ash-pit in which the rails are carried on steel I-beams is a typical example of a facility which rapidly deteriorates in use. The service to which such beams are subjected is often so severe that they are rendered worthless within a year or two after installation, and such beams comprise the principal portion of the facility from which salvage may be obtained. Bricks used in locomotive engine houses become discolored from smoke and gases so quickly after installation that they are usually of little value as second-hand material. It has been held that such structures have a salvage value sufficient only to pay for their removal. There are only a few structures the salvage value of which is insufficient to pay for their removal and, on the other hand, there are only a few which can be sold for more than this cost. A small water tank has but little salvage value since it cannot, as a rule, be used except by another railroad company and few railroads now install small water tanks at locomotive terminals. In many cases it will prove cheaper either to allow such tanks to remain in their present locations for the purpose of providing fire protection or water supply, or to scrap them.

In determining whether a facility should be entirely abandoned or transferred to a new location, consideration has necessarily been given not only to the character and condition of the facility, but also to the character of the service performed by the railroad. For example, under the proposed plan of electrification the Chicago & Western Indiana Railroad will operate all its trackage electrically and will therefore have no use for the turn-tables, ash-pits and water tanks now in service in connection with steam equipment. In such instances, equipment of this character will normally be sold for removal. The trunk lines, on the other hand, will continue to operate by steam beyond the proposed limits of electrification, and these lines may transfer portions of such facilities to new locations. However, the extent to which such procedure may be applicable to individual roads is not apparent from the information at hand, and since it is not practicable to undertake during construction any program involving the transfer of facilities other than machinery, no allowance has been made for such facilities beyond that of their salvage value.

Machinery, which commonly has a much higher salvage value than railroad structures, can usually be transferred to new locations at considerably less than the cost of new equipment. For the purpose of these estimates, it has been assumed that much of this machinery now used for steam equipment may be retained in present locations for the care of electric equipment. The difference in the character of the repair work required on steam and on electric locomotives is not so great as to make impracticable the use of many machines now employed for repairs to steam locomotives in a similar service to electric locomotives or to other electric equipment. A few exceptional cases of minor importance have been ignored. Thus, in the case of the Chicago & Western Indiana Railroad, on which, under the proposed plan of electrification, steam operation will be abolished, there will be no further use for certain flue machinery. Since the total cost of this machinery is small and since it can probably be sold to recover a part of its original cost, the loss due to its abandonment has been regarded as negligible.

Illustrations of typical structures which, in the event of electrification, will serve no further useful purpose to the railroads, are presented as figs. 651 to 670, inclusive.

213.091 Value of Property to be Abandoned: In conformity with the foregoing general principles, it was found that in the event of electrification the principal existing facilities which will be rendered worthless to the railroads and which, under the plans of the Committee, will be abandoned, are as follows:

Locomotive engine houses	42
Stalls in locomotive engine houses	872
Coaling stations	53
Water tanks	96

The original cost, the value as going facilities in 1912 and the salvage value of this property, based upon the reports and estimates effective for the year 1912 as described in the preceding sections, are as follows:

First cost of property	$3,127,259
Present value of property	2,318,604
Salvage value of property	249,000

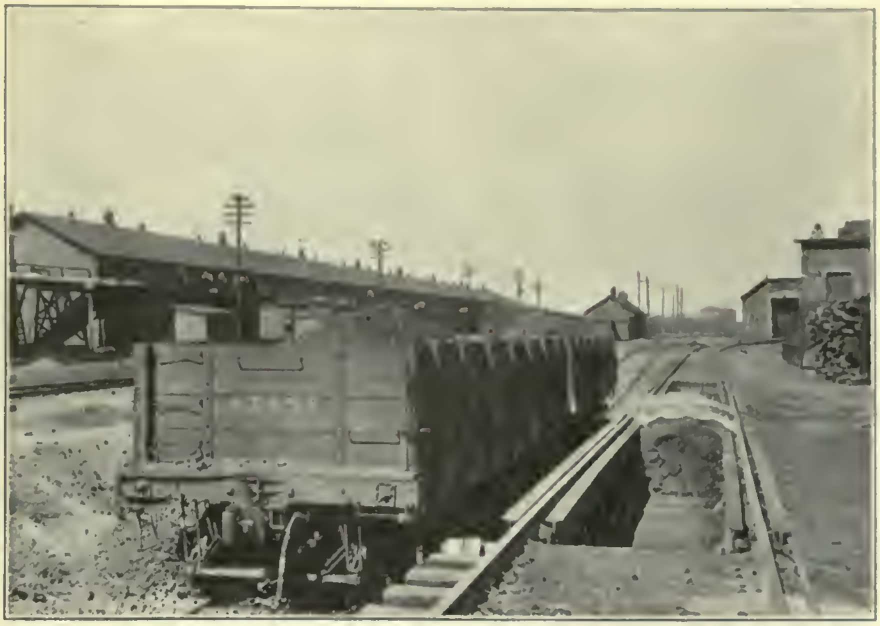


FIG. 651. FACILITIES TO BE ABANDONED. Locomotive ash-pit of the Atchison, Topeka & Santa Fe Railway in the Corwith Yard. This pit is 81 feet long and is typical of many shovel-pits in common use in the Chicago terminals. Facilities of this type in Chicago will, in the event of electrification, serve no further useful purpose in their present locations.

FIG. 652. FACILITIES TO BE ABANDONED. Locomotive ash-pit of the Chicago & Western Indiana Railroad at 49th and Butler streets. This double pit is equivalent to a single pit 450 feet long. It accommodates more than 100 locomotives daily. In the event of electrification, this structure will be rendered worthless in its present location. Approximately 5 per cent of its original cost of $30,000 could be recovered in salvage.

FIG. 653. FACILITIES TO BE ABANDONED. Locomotive ash-pit of the Lake Shore & Michigan Southern Railway, near 63d Street and Indiana Avenue. This is a double pit 180 feet long and is a good example of a high-class shovel-pit. The salvage of a pit of this type is very small.

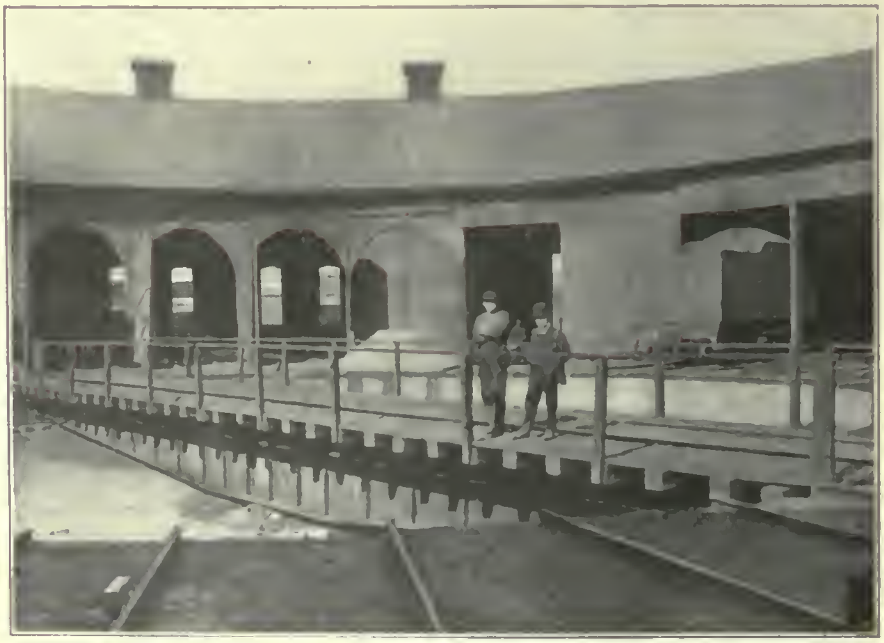


FIG. 654. FACILITIES TO BE ABANDONED. Eighty-foot deck plate-girder locomotive turn-table of the Baltimore & Ohio Railroad, near 86th Street and Brandon Avenue. This table is fitted with an air tractor for turning. In the event of electrification, the pit would be rendered worthless in its present location.

FIG. 655. FACILITIES TO BE ABANDONED. Seventy-five-foot half-through plate-girder locomotive turn-table of the Atchison, Topeka & Santa Fe Railway at the Corwith Yard engine house. This table is turned by means of an air tractor, and illustrates a type of structure which, in the event of electrification, would be rendered worthless to the railroad in its present location.

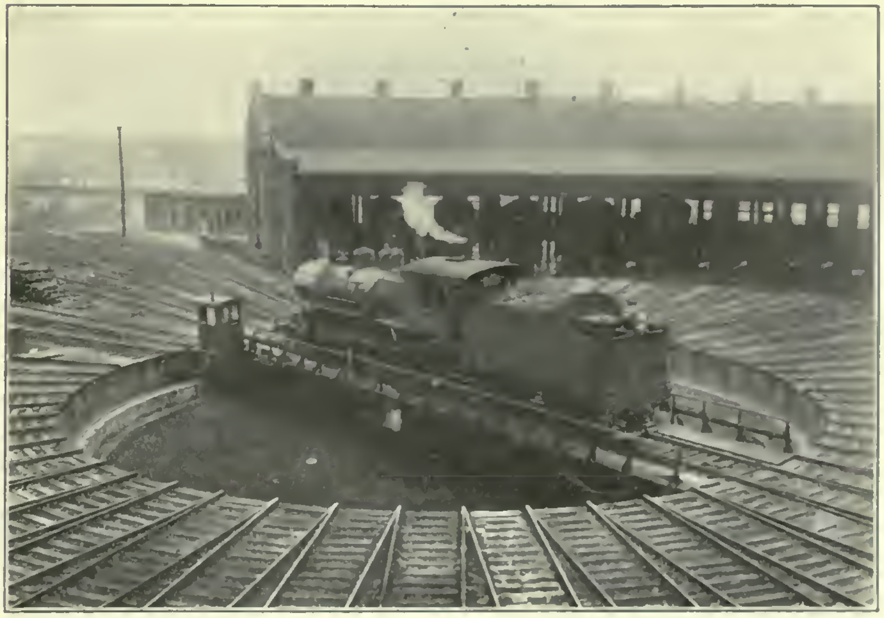


FIG. 656. FACILITIES TO BE ABANDONED. Turn-table and pit of the Lake Shore & Michigan Southern Railway, near 63d Street and Indiana Avenue. This is a 90-foot deck plate-girder turn-table with electric tractor and is typical of many such structures in Chicago. The pit has a concrete back wall and is exceptionally deep. In the event of electrification, this table would be of no further use to the railroad in its present location.

FIG. 657. FACILITIES TO BE ABANDONED. Water tanks of the Lake Shore & Michigan Southern Railway at 63d Street and Michigan Avenue. These tanks are of wooden construction throughout. In the event of electrification, they will be rendered worthless to the railroad in their present location. Owing to the necessities of operation during construction it will not be possible to transfer them to a new location until the need for similar facilities elsewhere has been met. They are, therefore, regarded as property to be abandoned.

FIG. 658. FACILITIES TO BE ABANDONED. Water tank of the Chicago & North Western Railway at 16th and S. Wood streets. This tank has a capacity of approximately 77,000 gallons, is in excellent condition, and is typical of many such structures within the proposed limits of electrification. In the event of electrification, it would be rendered worthless to the railroad in its present location.

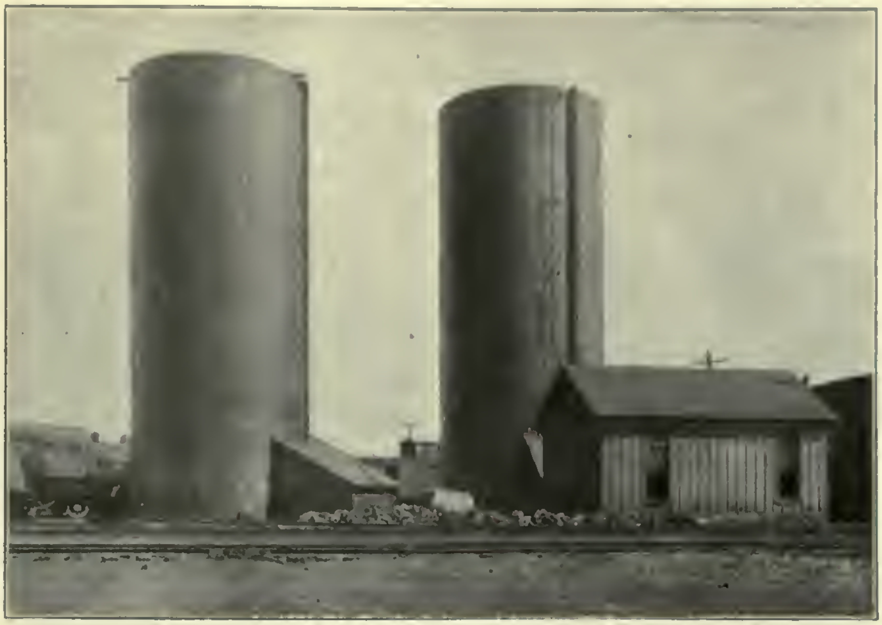


FIG. 659. FACILITIES TO BE ABANDONED. Steel water tanks in the Corwith Yard of the Atchison, Topeka & Santa Fe Railway. These tanks are 24 feet in diameter and 60 feet high, and hold 200,000 gallons each. In the event of electrification, they would be rendered worthless to the railroad in their present location. The two tanks here shown are the largest, for locomotive purposes, in the Chicago terminals.

FIG. 660. FACILITIES TO BE ABANDONED. Wooden water tank of the Chicago, Rock Island & Pacific Railway, near 47th Street and Armour Avenue. This tank represents a type of railroad structure which is common in the city of Chicago. It has a capacity of about 35,000 gallons, and is a wooden tub on a wooden frame. In the event of electrification, tanks of this type will be rendered worthless in their present locations.

FIG. 661. FACILITIES TO BE ABANDONED. Locomotive engine house of the Illinois Central Railroad at E. 26th Street and Lake Michigan. This is a 20-stall structure built in 1898. Stalls are 75 feet long, and the construction is of the usual type with brick walls and wooden roof. Immediately to the south of this building is a second engine house having 23 stalls. In the event of electrification, this building would be rendered worthless to the railroad.

FIG. 662. FACILITIES TO BE ABANDONED. Locomotive engine house of the Chicago & North Western Railway, near 14th Place and S. Robey Street. This building has 12 stalls, each 64 feet long, and is of an early type of construction. In the event of electrification, it would be rendered worthless to the railroad.

FIG. 663. FACILITIES TO BE ABANDONED. Locomotive engine house of the Chicago, Burlington & Quincy Railroad, near 12th and Canal streets. This house has 15 stalls, each 60 feet long, and in the event of electrification, would be a total loss, since the materials are not suitable for use in new construction.

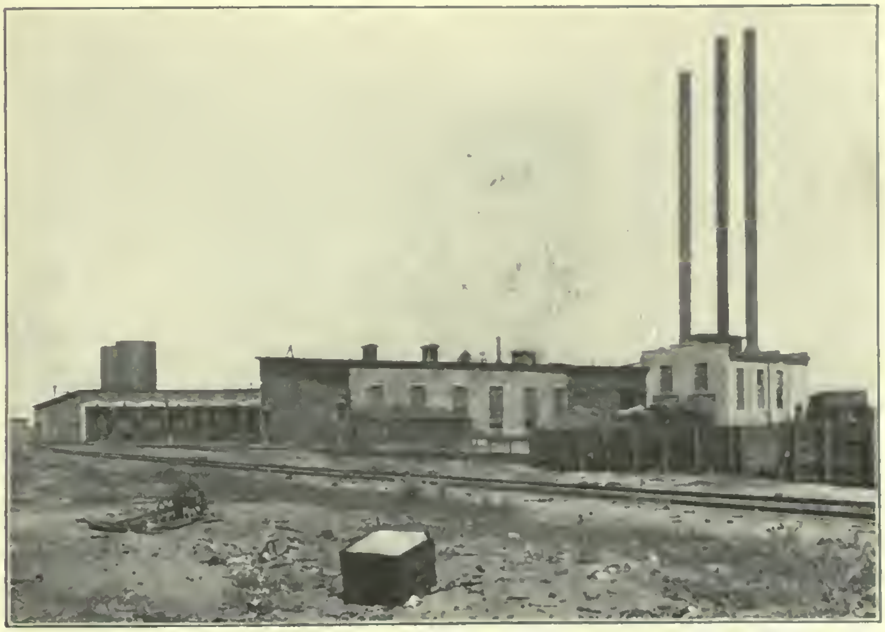


FIG. 664. FACILITIES TO BE ABANDONED. Locomotive engine house of the Atchison, Topeka & Santa Fe Railway, near W. 42d Street and S. Central Park Avenue. This house has 31 stalls, each 81 feet long. Seven of the stalls are used as a repair shop. Buildings of this kind are generally of brick construction. Many of them are old and the materials of which they are built have deteriorated due to the effects of smoke and gases so that the salvage value is only sufficient, it has been estimated, to cover the cost of wrecking and removing them.

FIG. 665. FACILITIES TO BE ABANDONED. Wooden coaling station of the Chicago & North Western Railway, near N. Karlov and Austin avenues. This station was built in 1902 at an approximate cost of $50,000 and has a storage capacity of 1,600 tons of coal. In the event of electrification, this structure will be rendered worthless.

FIG. 666. FACILITIES TO BE ABANDONED. Locomotive coaling station of the Chicago, Rock Island & Pacific Railway, near 47th Street and Armour Avenue. This station has a storage capacity of 500 tons. An inclined belt-conveyor carries the coal from the receiving hopper to the storage bins. In the event of electrification, the structure would be rendered worthless.

FIG. 667. FACILITIES TO BE ABANDONED. Locomotive coaling station of the Atchison, Topeka & Santa Fe Railway at Corwith Yard. This station has a storage capacity of 300 tons, and is operated by a gasoline engine. In the event of electrification, the station would be rendered worthless to the railroad. Beyond the coaling station is shown a sand house which could probably be utilized in its present location for furnishing sand to electric locomotives.

FIG. 668. FACILITIES TO BE ABANDONED. Mechanical coaling station of the Lake Shore & Michigan Southern Railway at 63d Street and Michigan Avenue. This station has a storage capacity of 600 tons. In the event of electrification, this station will be rendered worthless to the railroad in its present location.

FIG. 669. FACILITIES TO BE ABANDONED. Locomotive coaling station of the Illinois Central Railroad at E. 26th Street and Lake Michigan. This station has a storage capacity of 500 tons and was built in 1906 at an approximate cost of $17,000. From this chute about 400 tons of coal are taken each 24 hours. It will be rendered worthless in the event of electrification.

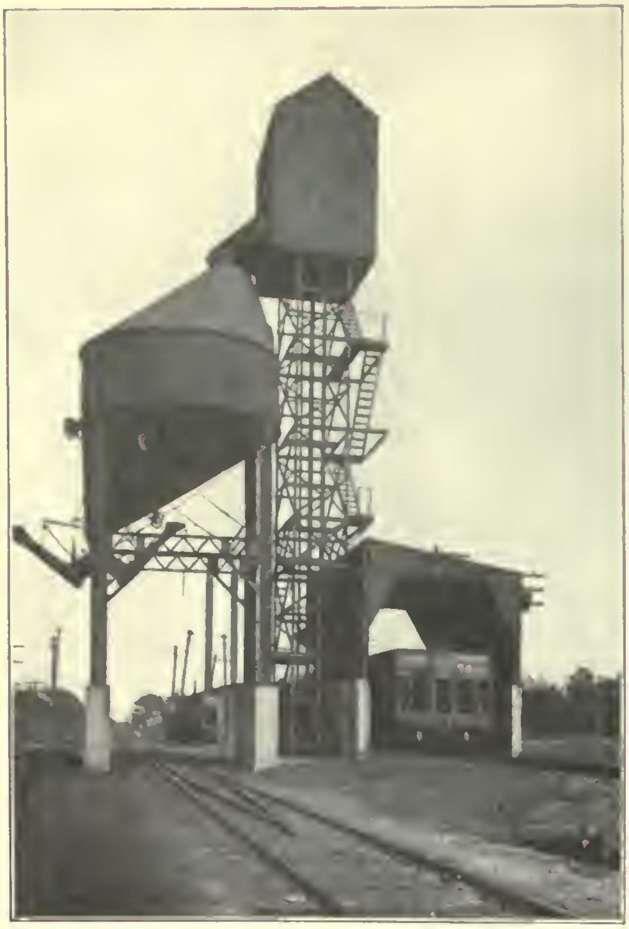


FIG. 670. FACILITIES TO BE ABANDONED. Mechanical coaling station of the Baltimore & Ohio Chicago Terminal Railroad, near Harvey Junction. This station has a steel storage bin of 150 tons capacity, serving two tracks. It is operated with a bucket hoist, which has a capacity of 1.5 tons. In the event of electrification, this station will be rendered worthless to the railroad in its present location.

A summarized statement, by roads, of the character and value to the railroads, as going facilities, of property which will be abandoned in the event of electrification is presented as table CCCXXIX.

A statement of the first cost, estimated value in 1912, salvage value and net value of property which will be dissipated or abandoned in the event of electrification by roads, is presented as table CCCXXX. The net value set forth represents the estimated value in 1912 less the salvage value.

213.092 Total Value of Property to be Abandoned: The first cost, estimated value as going facilities in 1912, salvage value and net value of property which will be abandoned in the event the steam locomotive is eliminated from the city of Chicago, are set forth in table CCCXXX, as scheduled for the year 1912. An extension of such facilities will, in the ordinary course of business, continue subsequent to 1912. While the rate of increase cannot be accurately determined, it may safely be assumed as not less than the rate of increase in track mileage, namely, 3 per cent per annum. It will be reasonable also to assume that, in the event electrification is decided upon, all extensions of terminal facilities for the care of steam locomotives within the proposed limits of electrification will cease as soon as the plans for the prospective change become operative. A single factor of extension is, therefore, applied to the foregoing estimates, as follows:

	PER CENT
Growth of facilities ultimately to be abandoned, at 3 per cent per annum for 4 years, December 31, 1912, to December 31, 1916	12.0

The values thus derived may be accepted as the estimated total values of the property which, in the event of electrification, will be abandoned. The first cost, the value to the railroads as going facilities, the salvage value and the net value of property to be abandoned upon the completion of the electric installation in 1922 are set forth, by roads, in table CCCXXXI.

TABLE CCCXXIX. VALUE TO THE RAILROADS, AS GOING FACILITIES, OF PROPERTY WHICH WILL BE ABANDONED IN THE EVENT OF ELECTRIFICATION

(Basis of 1912)

Railroad	Facilities to be Abandoned					
	Ash-Pits	Coaling Stations	Engine Houses	Turn-Tables	Miscellaneous	Total
1	2	3	4	5	6	7
Atchison, Topeka & Santa Fe Ry	$ 1,740	$14,000	$ 48,000	$ 5,000	$ 6,100	$ 74,840
Baltimore & Ohio R. R.	2,000	12,000	50,000	5,000	1,600	70,600
Baltimore & Ohio Chicago Terminal R. R.	3,300	16,000	27,000	3,500	7,500	57,300
Calumet, Hammond & Southeastern R. R.		1,748			1,185	2,933
Chesapeake & Ohio Ry. of Indiana						
Chicago & Alton R. R.	2,000	7,500	16,000		2,800	28,300
Chicago & Calumet River R. R.						
Chicago & Eastern Illinois R. R.						
Chicago & Erie R. R.						
Chicago & North Western Ry.	42,000	66,800	209,200	28,500	21,100	367,600
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	23,600	29,600	136,000	15,000	22,000	227,100
Chicago, Burlington & Quincy R. R.	2,350	4,500	113,000	17,000	6,300	143,150
Chicago Great Western R. R.	2,000	5,000	13,000	7,500	1,000	28,500
Chicago, Indiana & Southern R. R.						
Chicago, Indianapolis & Louisville Ry.						
Chicago Junction Ry.	5,700	5,100	38,000	6,000	20,500	75,300
Chicago, Milwaukee & St. Paul Ry.	7,000	34,000	200,000	20,000	10,200	271,200
Chicago River & Indiana R. R.						
Chicago, Rock Island & Pacific Ry.	5,700	12,500	37,000	7,600	22,000	84,800
Chicago Short Line Ry.		500			1,500	2,000
Chicago Union Transfer Ry.						
Chicago, West Pullman & Southern R. R	1,100	900			200	2,200
Elgin, Joliet & Eastern Ry.	3,600	10,400	17,000	7,000	4,000	42,900
Grand Trunk Western Ry.	1,100	7,000	35,000	4,800	7,300	55,200
Illinois Central R. R.	14,500	41,700	155,150	23,000	23,113	257,463
Illinois Northern Ry.	350	1,100				1,450
Indiana Harbor Belt R. R.	600	300	2,000			2,900
Lake Shore & Michigan Southern Ry.	10,000	25,000	92,000	9,500	19,100	155,600
Michigan Central R. R.	500	3,300	16,500	4,500	9,400	34,200
Minneapolis, St. Paul & Sault Ste. Marie Ry.						
New York, Chicago & St. Louis R. R.	3,500	5,000	11,500	5,000	3,100	28,100
Pere Marquette R. R.	900		18,000	4,000	1,800	24,700
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	4,000	3,650	10,500	4,000	7,576	30,626
Pittsburgh, Fort Wayne & Chicago Ry.	6,000	30,400	137,500	10,000	17,700	201,600
Pullman Railroad	100	350	12,000	1,500	300	14,250
Wabash Railroad	700	5,000	19,680	4,000	4,412	33,792
Totals	$145,240	$343,348	$1,414,030	$192,400	$223,586	$2,318,604

The amounts set forth in the last column of table CCCXXXI, totaling $2,317,957, represent the estimated value in 1922 less the estimated salvage value at that time of property which, in the event of electrification, will be rendered useless. This amount cannot be charged to capital and must, therefore, stand as an independent item in representing property wholly dissipated.

213.093 Costs of Transferring Machinery to New Locations: In the event of electrification it will be practicable to transfer certain machinery, such as stationary engines, lathes, milling machines, drill presses and other shop machinery, from present locations to new locations in which this equipment may continue to serve a useful purpose to the railroads. In most cases machinery now used for the care of steam locomotives within the city will be removed to the proposed new transfer yards where facilities for the care of both steam and electric equipment are to be provided. In some instances certain shop machinery will be retained in its present location for the care of electric equipment, or for continuation of the service it now performs in connection with coach yards, buildings or other facilities not directly related to the steam locomotive. In a few cases, as on roads which are to be completely electrified and which after electrification will maintain no steam service whatever, certain special machinery suitable only for the repair of steam locomotives will be abandoned, and the value of such machinery is included with that of other abandoned property of which account has already been taken. Machinery which is out of date but is still kept in service has been regarded, for the purposes of these estimates, as available for transfer, since it is not the purpose to charge electrification with the cost of improving the character of an existing related facility.

The cost of transferring machinery from present locations to proposed new locations is regarded as a charge against electrification.

The estimated costs, on the basis of the establishment existing in 1912, of transferring such

TABLE CCCXXX. FIRST COST, ESTIMATED VALUE AS GOING FACILITIES IN 1912, SALVAGE VALUE AND NET VALUE, BY ROADS, OF PROPERTY WHICH WILL BE ABANDONED IN THE EVENT OF ELECTRIFICATION
(Basis of 1912)

Railroad	Facilities to be Abandoned			
	First Cost	Present Value	Salvage Value	Net Value
1	2	3	4	5
Atchison, Topeka & Santa Fe Railway	$107,931	$ 74,840	$10,000	$ 64,840
Baltimore & Ohio Railroad	88,900	70,600	5,000	65,600
Baltimore & Ohio Chicago Terminal Railroad	84,580	57,300	14,000	43,300
Calumet, Hammond & Southeastern Railroad	3,124	2,933	....	2,933
Chesapeake & Ohio Railway of Indiana	.	. . .	. . . . .	. . . . .
Chicago & Alton Railroad	47,600	28,300	5,000	23,300
Chicago & Calumet River Railroad	......	....	......	....
Chicago & Eastern Illinois Railroad	......	....	......	....
Chicago & Erie Railroad	.	. . .	....	....
Chicago & North Western Railway	541,599	367,600	33,000	334,600
Chicago & Western Indiana Railroad and the Belt Railway of Chicago	299,769	227,100	31,000	196,100
Chicago, Burlington & Quincy Railroad	198,760	143,150	16,000	127,150
Chicago Great Western Railroad	39,500	28,500	3,000	25,500
Chicago, Indiana & Southern Railroad	....	....	......	....
Chicago, Indianapolis & Louisville Railway	...	...	...	....
Chicago Junction Railway	97,300	75,300	16,000	59,300
Chicago, Milwaukee & St. Paul Railway	350,937	271,200	19,000	252,200
Chicago River & Indiana Railroad	. . .	.	. .	. . .
Chicago, Rock Island & Pacific Railway	115,100	84,800	7,000	77,800
Chicago Short Line Railway	3,000	2,000	....	2,000
Chicago Union Transfer Railway	.	....	....	... .
Chicago, West Pullman & Southern Railroad	3,100	2,200	.. ..	2,200
Elgin, Joliet & Eastern Railway	62,800	42,900	2,000	40,900
Grand Trunk Western Railway	71,700	55,200	8,000	47,200
Illinois Central Railroad	358,293	257,463	26,000	231,463
Illinois Northern Railway	1,850	1,450	....	1,450
Indiana Harbor Belt Railroad	5,300	2,900	....	2,900
Lake Shore & Michigan Southern Railway	162,435	155,600	13,000	142,600
Michigan Central Railroad	62,020	34,200	5,000	29,200
Minneapolis, St. Paul & Sault Ste. Marie Railway	....	....	....	....
New York, Chicago & St. Louis Railroad	49,878	28,100	7,000	21,100
Pere Marquette Railroad	33,700	24,700	3,000	21,700
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	40,676	30,626	4,000	26,626
Pittsburgh, Fort Wayne & Chicago Railway	236,616	201,600	11,000	190,600
Pullman Railroad	19,091	14,250	2,000	12,250
Wabash Railroad	41,700	33,792	9,000	24,792
Totals	$3,127,259	$2,318,604	$249,000	$2,069,604

machinery as is available for removal to new locations are set forth, by railroads, in table CCCXXXII.

213.094 Total Cost of Transferring Machinery to New Locations: The cost of transferring the machinery enumerated in the preceding section, as scheduled for the year 1912, is set forth in table CCCXXXII. Additions to such machinery will, in the ordinary course of business, continue subsequent to 1912, and while the rate of increase cannot be accurately determined it may safely be assumed at not less than the rate of increase in track mileage, namely, 3 per cent per annum. It will be reasonable to assume also that, in the event electrification is decided upon, all installations of transferable machinery will cease when the plans for the prospective changes become definitely operative. The factor of extension in this case, therefore, is:

	PER CENT
To cover growth at 3 per cent per annum for 4 years, from December 31, 1912, to December 31, 1916. .	12.0

Upon this basis the total cost, by railroads, of the transfer of machinery to new locations is set forth by table CCCXXXIII.

213.095 Character and Extent of New Facilities: The electrification of the Chicago railroad terminals will necessitate a considerable amount of new construction, involving such facilities as engine houses, ash-pits, machine shops, water tanks, houses for electric locomotives and multiple-unit equipment, coaling stations and trackage. Most of this new construction will be at transfer yards which, in nearly all cases, will be located at points marking the limits of complete electrification. In estimating the extent of these new facilities, the following general principles have been recognized:

1. The extent of each type of new facility has been determined for each road with regard to the present requirements of the road. It has been the purpose to adopt a program such as the roads might voluntarily accept in the event of rebuilding facilities to meet present de-

TABLE CCCXXXI. FIRST COST, VALUE TO THE RAILROADS AS GOING FACILITIES, SALVAGE VALUE AND NET VALUE, BY ROADS, OF PROPERTY WHICH WILL BE ABANDONED IN THE EVENT OF ELECTRIFICATION
(Dec. 31, 1922)

Railroad	Facilities to be Abandoned			
	First Cost	Present Value	Salvage Value	Net Value
1	2	3	4	5
Atchison, Topeka & Santa Fe Railway	$120,883	$ 83,821	$11,200	$ 72,621
Baltimore & Ohio Railroad	99,568	79,072	5,600	73,472
Baltimore & Ohio Chicago Terminal Railroad	94,730	64,176	15,680	48,496
Calumet, Hammond & Southeastern Railroad	3,499	3,285	....	3,285
Chesapeake & Ohio Railway of Indiana*	....	....	....	....
Chicago & Alton Railroad	53,312	31,696	5,600	26,096
Chicago & Calumet River Railroad*	....	....	....	....
Chicago & Eastern Illinois Railroad*	....	....	....	....
Chicago & Erie Railroad*	....	....	....	....
Chicago & North Western Railway	606,591	411,712	36,960	374,752
Chicago & Western Indiana Railroad and the Belt Railway of Chicago	335,741	254,352	34,720	219,632
Chicago, Burlington & Quincy Railroad	222,611	160,328	17,920	142,408
Chicago Great Western Railroad	44,240	31,920	3,360	28,560
Chicago, Indiana & Southern Railroad*	....	....	....	....
Chicago, Indianapolis & Louisville Railway*	....	....	....	....
Chicago Junction Railway	108,976	84,336	17.920	66.416
Chicago, Milwaukee & St. Paul Railway	393,050	303,744	21,280	282,464
Chicago River & Indiana Railroad*	....	....	....	....
Chicago, Rock Island & Pacific Railway	128.912	94,976	7.840	87,136
Chicago Short Line Railway	3,360	2,240	....	2,240
Chicago Union Transfer Railway*	....	....	....	....
Chicago, West Pullman & Southern Railroad	3.472	2,464	....	2,464
Elgin, Joliet & Eastern Railway	70,336	48,048	2,240	45,808
Grand Trunk Western Railway	80,304	61,824	8,960	52,864
Illinois Central Railroad	401,288	288,359	29,120	259,239
Illinois Northern Railway	2,072	1,624	....	1,624
Indiana Harbor Belt Railroad	5,936	3,248	....	3,248
Lake Shore & Michigan Southern Railway	181,927	174.272	14,560	159,712
Michigan Central Railroad	69,462	38,304	5,600	32,704
Minneapolis, St. Paul & Sault Ste. Marie Railway*	....	....	....	....
New York, Chicago & St. Louis Railroad	55,863	31,472	7,840	23,632
Pere Marquette Railroad	37,744	27,664	3,360	24,304
Pittsburgh, Cincinnati, Chicago & St. Louis Railway	45,557	34,301	4,480	29,821
Pittsburgh, Fort Wayne & Chicago Railway	265,010	225,792	12,320	213,472
Pullman Railroad	21,382	15,960	2,240	13,720
Wabash Railroad	46,704	37,847	10,080	27,767
Totals	$3,502,530	$2,596 837	$278,880	$2,317,957

* Has no property which will be abandoned.

TABLE CCCXXXII. ESTIMATED COSTS, BY ROADS, OF TRANSFERRING MACHINERY TO NEW LOCATIONS
(Basis of 1912)

Railroad	Cost
Atchison, Topeka & Santa Fe Ry.	$4,000
Baltimore & Ohio R. R.	4,000
Baltimore & Ohio Chicago Terminal R. R.	......
Calumet, Hammond & Southeastern R. R.	......
Chesapeake & Ohio Ry. of Indiana	......
Chicago & Alton R. R.	2,000
Chicago & Calumet River R. R.	......
Chicago & Eastern Illinois R. R.	......
Chicago & Erie R. R.	......
Chicago & North Western Ry.	......
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	......
Chicago, Burlington & Quincy R. R.	5,000
Chicago Great Western R. R.	3,000
Chicago, Indiana & Southern R. R.	......
Chicago, Indianapolis & Louisville Ry.	......
Chicago Junction Ry.	......
Chicago, Milwaukee & St. Paul Ry.	4,000
Chicago River & Indiana R. R.	......
Chicago, Rock Island & Pacific Ry.	4,000
Chicago Short Line Ry.	......
Chicago Union Transfer Ry.	......
Chicago, West Pullman & Southern R. R.	......
Elgin, Joliet & Eastern Ry.	......
Grand Trunk Western Ry.	4,000
Illinois Central R. R.	5,000
Illinois Northern Ry.	......
Indiana Harbor Belt R. R.	......
Lake Shore & Michigan Southern Ry.	4,000
Michigan Central R. R.	2,000
Minneapolis, St. Paul & Sault Ste. Marie Ry.	......
New York, Chicago & St. Louis R. R.	4,000
Pere Marquette R. R.	2,000
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	......
Pittsburgh, Fort Wayne & Chicago Ry.	8,000
Pullman Railroad	......
Wabash Railroad	4,000
Total	$59,000

TABLE CCCXXXIII. TOTAL COST, BY ROADS, OF TRANSFERRING MACHINERY TO NEW LOCATIONS
(Dec. 31, 1922)

Railroad	Total Cost
Atchison, Topeka & Santa Fe Ry.	$6,535
Baltimore & Ohio R. R.	6,535
Baltimore & Ohio Chicago Terminal R. R.	......
Calumet, Hammond & Southeastern R. R.	......
Chesapeake & Ohio Ry. of Indiana	......
Chicago & Alton R. R.	3,267
Chicago & Calumet River R. R.	......
Chicago & Eastern Illinois R. R.	......
Chicago & Erie R. R.	......
Chicago & North Western Ry.	......
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	......
Chicago, Burlington & Quincy R. R.	8,166
Chicago Great Western R. R.	4,901
Chicago, Indiana & Southern R. R.	......
Chicago, Indianapolis & Louisville Ry.	......
Chicago Junction Ry.	......
Chicago, Milwaukee & St. Paul Ry.	6,535
Chicago River & Indiana R. R.	......
Chicago, Rock Island & Pacific Ry.	6,535
Chicago Short Line Ry.	......
Chicago Union Transfer Ry.	......
Chicago, West Pullman & Southern R. R.	......
Elgin, Joliet & Eastern Ry.	......
Grand Trunk Western Ry.	6,535
Illinois Central R. R.	8,166
Illinois Northern Ry.	......
Indiana Harbor Belt R. R.	......
Lake Shore & Michigan Southern Ry.	6,535
Michigan Central R. R.	3,267
Minneapolis, St. Paul & Sault Ste. Marie Ry.	....
New York, Chicago & St. Louis R. R.	6,535
Pere Marquette R. R.	3,267
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	......
Pittsburgh, Fort Wayne & Chicago Ry.	13,069
Pullman Railroad	......
Wabash Railroad	6,535
Total	$96,383

mands. It has not been the purpose, however, to make an elaborate provision for prospective development, nor to charge electrification with the expense of improving an existing facility beyond the extent believed necessary to meet present conditions.

2. The extent of new trackage to be provided under the estimates of the Committee is only such as is deemed necessary for the prompt change of locomotives and for the handling of motive power.

3. As a basis for estimates, standard plans have been prepared for transfer yards, electric locomotive houses, multiple-unit equipment houses and other similar facilities. Estimates have been based upon unit prices prevailing in Chicago for labor and material.

The new facilities to be supplied may be classified as follows:

1. Those which will be constructed at locations where there are now no side tracks or yard facilities.

2. Those which will be constructed as additions to existing yards, or on ground in such yards made available by the abandonment of present facilities.

In most cases it has been assumed that new facilities will be located at transfer yards, the choice of locations for which has been based upon the operating requirements of the road affected and upon the availability of land.

Where operating conditions make desirable the establishment of new facilities for the care of electric equipment at points at a distance from the transfer yards, the cost of such facilities, in addition to that of the major facilities to be provided at the transfer yards, is included in the estimates.

The locations selected for transfer yards are shown by the map presented as fig. 671.

A list of all proposed transfer yards as shown by fig. 671 is presented as table CCCXXXIV. In this table the term, "No present facilities," indicates that neither buildings nor side tracks now exist on the site of the proposed yard, and the term, "Addition to present yard," indicates that the required facilities for the care of steam and electric locomotives are to be constructed in, or adjacent to, an existing yard.

A plan of a standard transfer yard, including tracks and all accessory facilities for the convenient handling of trains and for the care of steam and electric equipment, is shown by fig.

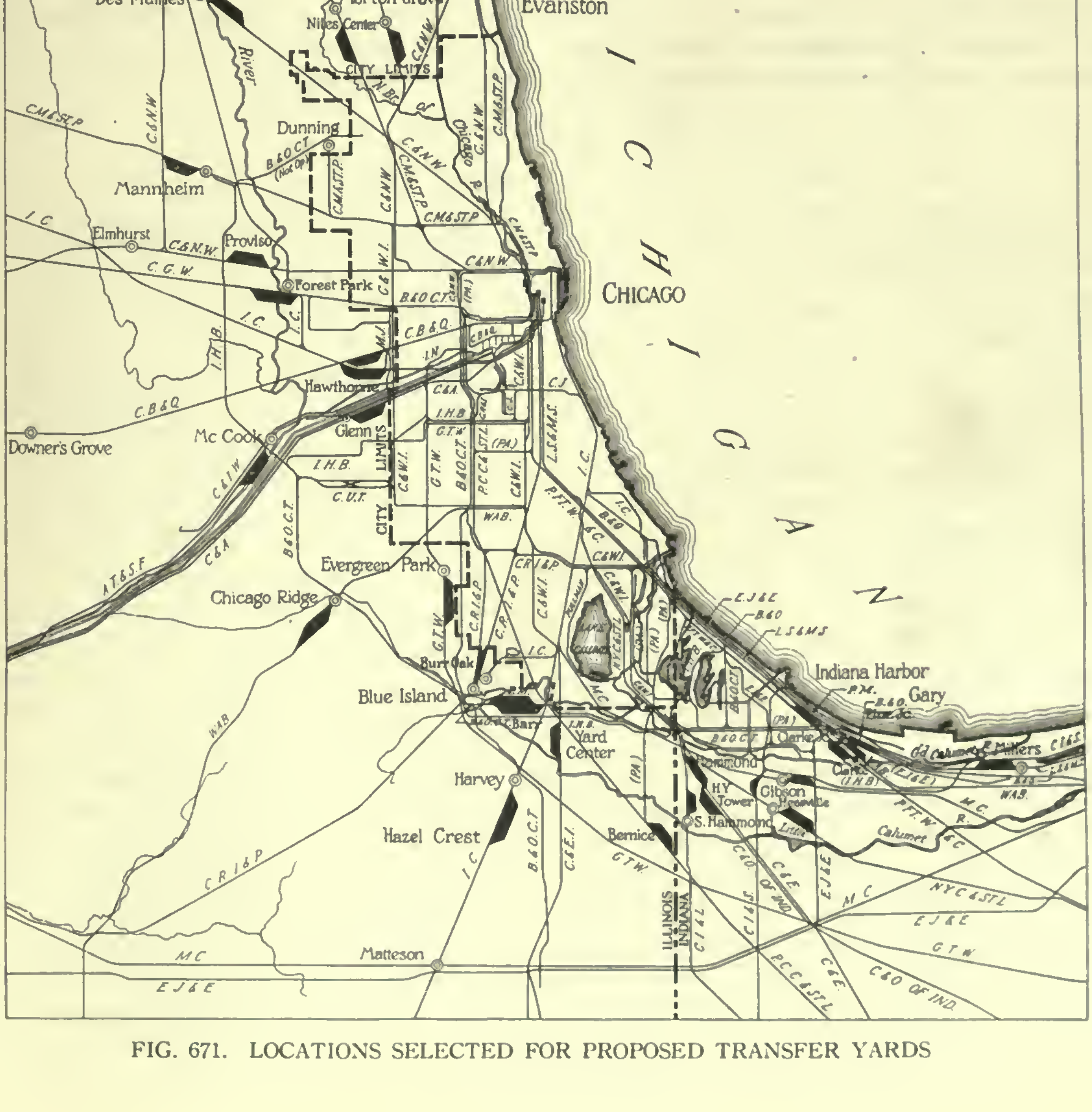


FIG. 671. LOCATIONS SELECTED FOR PROPOSED TRANSFER YARDS

672. The plan merely sets forth the elements of a transfer yard. Its use in formulating estimates of cost has involved modifications suited to the requirements of individual roads. The extent of the facilities provided by the estimates vary, for different roads, from the minimum of two sidings for inbound trains and one for outbound trains, with no structures, to the more complete group of facilities shown by the standard plan. In the case of a few of the larger roads, the estimates have provided for an even more elaborate group of facilities than that shown by the plan.

The standard transfer yard provides transfer tracks chiefly for the use of inbound trains. This provision is based upon the assumption that outbound trains, either freight or passenger, will generally be in such condition that they will need to be held at the point of transfer only long enough for the locomotives to be changed, a period of perhaps 5 minutes for passenger trains and 15 minutes for freight trains being considered sufficient. Thus, an outbound passenger train may be brought to a stop opposite the point marked "E," fig. 672, where the electric locomotive which has brought it from the city will be uncoupled and allowed to proceed directly to the electric locomotive house which is served by tracks Nos. 112 and 114. A steam locomotive previously brought from the roundhouse and placed on the short siding marked No. 141, may then be run on to the main track and attached to the train in readiness to continue the journey. Similarly, an inbound passenger train may be brought to a stop near the point "F." Here the steam locomotive will be uncoupled from the train and allowed to proceed through the crossover to the outbound track, from which it has access to the roundhouse over track No. 22. An electric locomotive, previously placed on the inbound main track at a proper distance ahead of the crossover or on a convenient siding which may be provided near the point "F," may

TABLE CCCXXXIV. PROPOSED TRANSFER YARDS

Railroad	Location	Remarks
Atchison, Topeka & Santa Fe Ry.	McCook, Ill	No present facilities
Baltimore & Ohio R. R.	Pine Junction, Ind.	No present facilities
Baltimore & Ohio Chicago Terminal R. R.	Barr Yard	Addition to present yard
Calumet, Hammond & Southeastern R. R.*		
Chesapeake & Ohio Ry. of Indiana	HY Tower Yard, Ind	Addition to present yard
Chicago & Alton R. R.	Glenn Yard	Addition to present yard
Chicago & Calumet River R. R.*		
Chicago & Eastern Illinois R. R.	Yard Center, Ill.	Addition to present yard
Chicago & Erie R. R.	Hammond, Ind	Addition to present yard
Chicago & North Western Ry.	Waukegan, Ill	No present facilities
Chicago & North Western Ry.	Niles Center, Ill	No present facilities
Chicago & North Western Ry.	Desplaines, Ill	No present facilities
Chicago & North Western Ry.	Proviso, Ill.	Addition to present yard
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago*.		
Chicago, Burlington & Quincy R. R.	Hawthorne, Ill.	Addition to present yard
Chicago Great Western R. R.	Forest Park, Ill.	Transfer tracks only
Chicago, Indiana & Southern R. R.	Gibson, Ind.	Addition to present yard
Chicago, Indianapolis & Louisville Ry.	So. Hammond, Ind.	Addition to present yard
Chicago Junction Ry.*		
Chicago, Milwaukee & St. Paul Ry.	Morton Grove, Ill.	No present facilities
Chicago, Milwaukee & St. Paul Ry.	Mannheim, Ill.	Addition to present yard
Chicago River & Indiana R. R.*		
Chicago, Rock Island & Pacific Ry.	Burr Oak Yard	Addition to present yard
Chicago Short Line Ry.*		
Chicago Union Transfer Ry.*		Facility tracks only
Chicago, West Pullman & Southern R. R.*		
Elgin, Joliet & Eastern Ry.*		
Grand Trunk Western Ry.	Evergreen Park, Ill.	No present facilities
Illinois Central R. R.	Hazel Crest, Ill.	No present facilities
Illinois Central R. R.	Hawthorne, Ill.	Addition to present yard
Illinois Northern Ry.*		
Indiana Harbor Belt R. R.*		Facility tracks only
Lake Shore & Michigan Southern Ry.	Millers, Ind.	No present facilities
Michigan Central R. R.	Gibson, Ind.	No present facilities
Minneapolis, St. Paul & Sault Ste. Marie Ry.*		To use Hawthorne yard of I. C. R. R.
New York, Chicago & St. Louis R. R.	Hessville, Ind.	No present facilities
Pere Marquette R. R.	Barr Yard	No present facilities
Pere Marquette R. R.	Clarke Junction, Ind.	No present facilities
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	Bernice, Ill.	No present facilities
Pittsburgh, Fort Wayne & Chicago Ry.	Clarke, Ind.	No present facilities
Pullman Railroad*		
Wabash Railroad	Chicago Ridge, Ill	No present facilities
Wabash Railroad	Clarke Junction, Ind.	No present facilities

* No transfer facilities required.

then be attached to the train in readiness to proceed with it to its destination.

For outbound freight trains, the change of motive power may be made upon the outbound main track in a manner similar to that described for passenger trains. When traffic conditions prohibit this, the train may be pulled into the long siding marked "transfer siding," and the change from electric to steam motive power made from that position. Additional tracks parallel to the transfer siding are to be provided on individual roads as may be required by traffic conditions.

In the case of inbound freight trains, the change may be made either upon the main track, as with passenger trains, or on one of the sidings numbered 1, 2, 3, 4, 5 (fig. 672). The steam locomotive may uncouple from the train and proceed to the roundhouse over track No. 22. At such time as may be found convenient, an electric locomotive may be attached and the train taken to its destination in the city. Since the destinations for freight trains are much more numerous than those for passenger trains, the delays in reaching them will be proportionately greater, and more extensive trackage must therefore be provided for inbound freight trains. Electric locomotives, moreover, may not always be available for the prompt handling of freight trains, the movements of which frequently do not conform to schedules.

For the reasons mentioned, the specifications upon which estimates of cost are based ordinarily provide for five inbound tracks on which trains awaiting change from steam to electric locomotives may stand. In the case of the smaller roads this number has been reduced to a number deemed sufficient for the existing business.

It may generally be found desirable to combine the functions of a transfer yard with those of a classification or switching yard. Such an arrangement will permit incoming freight trains to be broken up at the point at which the steam locomotive is uncoupled. The full development of such a plan would result in the building of extensive freight yards for general purposes at points of transfer. The possession of such yards would constitute an added facility of great value to certain roads, but it can hardly be assumed that such establishments are necessary adjuncts to electrification. While, therefore, individual roads may develop the transfer yard, such as is herein provided, into a much more extensive arrangement of tracks, the added cost of such an elaboration, in excess of that necessary for transfer purposes, is not included in these estimates.

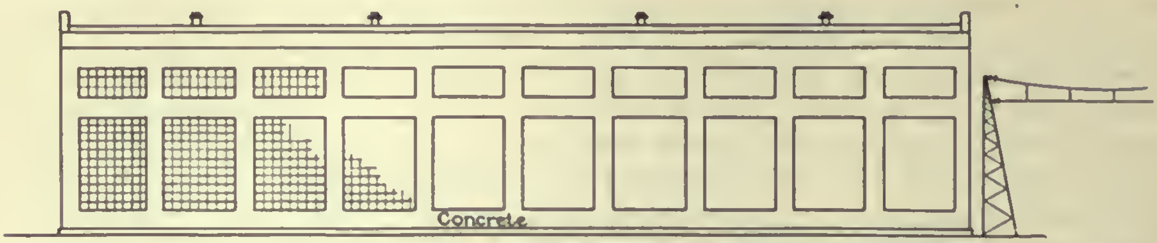
The extent of the new facilities in transfer yards, for which the estimates provide, has been based on the minimum requirements for economical operation. Individual requirements, as interpreted by officials of the various roads, may involve material extensions to the plan herein outlined.

Plans upon which have been based estimates of the cost of standard buildings required for housing and inspecting multiple-unit cars and for machine shop purposes, for the care of electric locomotives, are shown by figs. 673 to 676, inclusive.

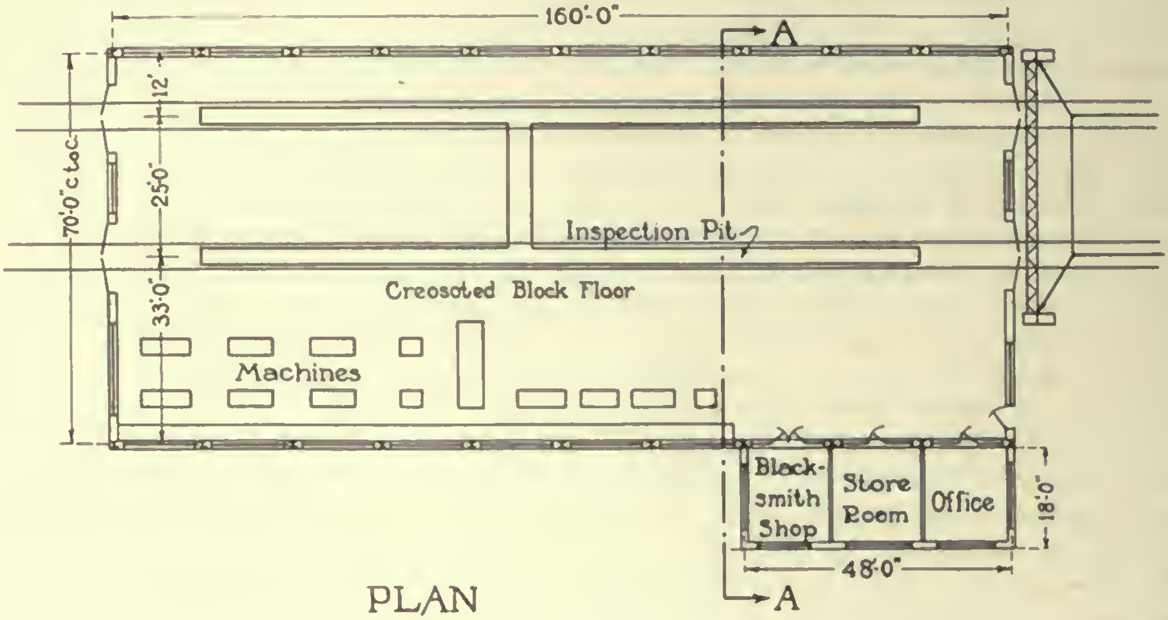
Fig. 673 shows plan and elevations of a standard house for the care of electric locomotives at a location where the facilities of a general machine shop are not available. Certain shop facilities are therefore to be provided in this building. Such a building will be required in locations where provision is needed for the care of electric locomotives which cannot conveniently be taken to the more extensive shops at transfer yards. An example of conditions which give rise to the need of such an arrangement is to be seen in the Garfield Boulevard plant of the Pittsburgh, Fort Wayne & Chicago Railway, from which, it is assumed, the present machine shop facilities will be removed to the new transfer yard to be provided at Clarke Junction, Ind. Since, under the plan of electrification, the Garfield Boulevard Yard will be a terminal for electric locomotives, shop facilities for all except the heavier repairs must be provided.

Fig. 674 shows a building for the care of electric locomotives where general machine shop facilities are available in the immediate vicinity. This building will serve to meet the requirements in locations such as the proposed Evergreen Park Transfer Yard of the Grand Trunk Western Railway. This yard, under the plan of electrification, will have a separate general machine shop for the care of both steam and electric locomotives; hence, provision for shop facilities will not be required in the electric locomotive house.

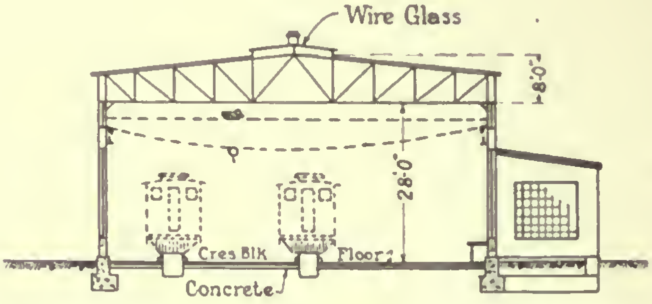
Fig. 675 shows plan and elevations of a standard house for the care of multiple-unit cars which, in



SIDE ELEVATION



PLAN



SECTION A-A

FIG. 673. STANDARD HOUSE FOR ELECTRIC LOCOMOTIVES FOR USE WHERE THE FACILITIES OF A GENERAL MACHINE SHOP ARE NOT AVAILABLE

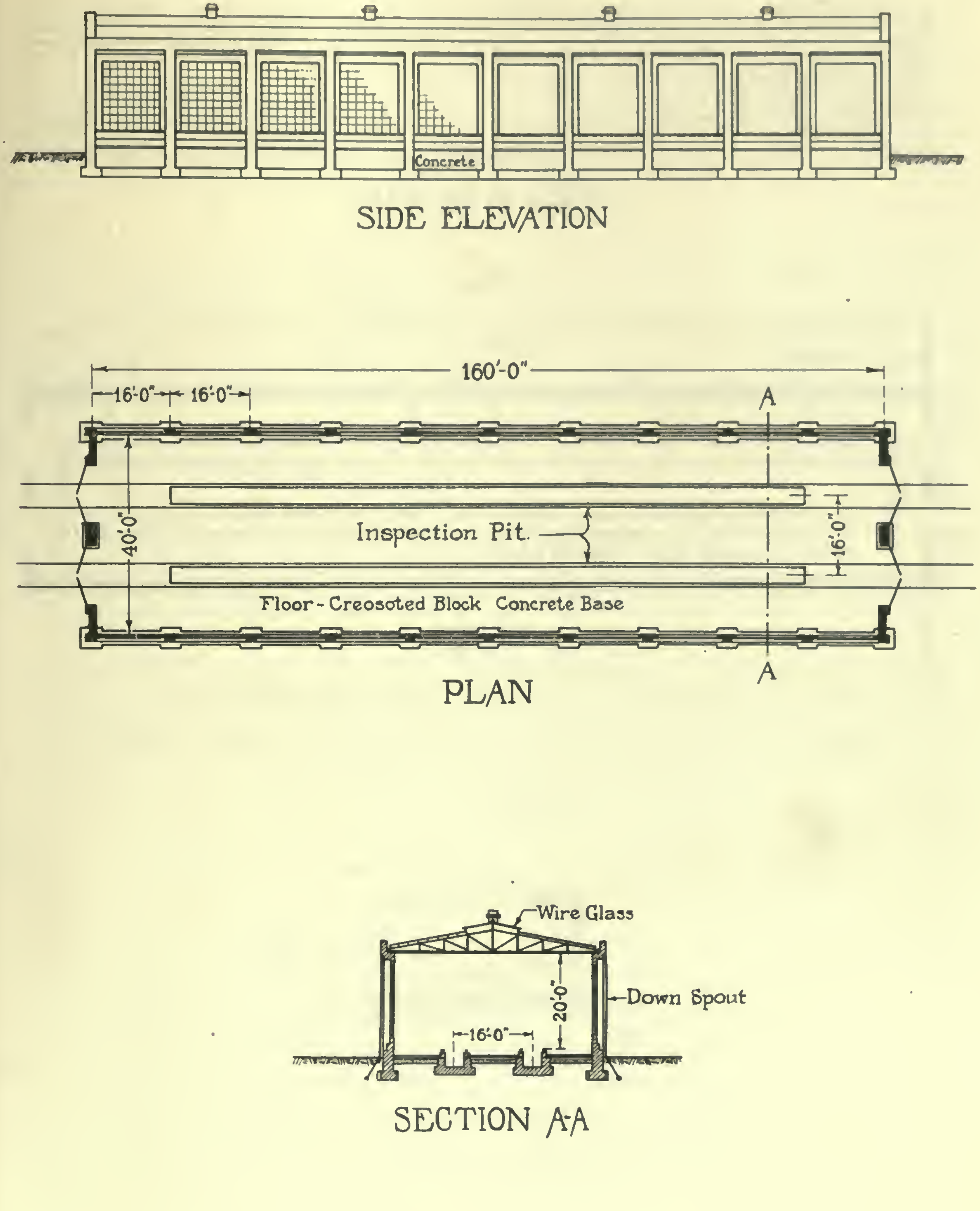


FIG. 674. STANDARD HOUSE FOR ELECTRIC LOCOMOTIVES FOR USE WHERE THE FACILITIES OF A GENERAL MACHINE SHOP ARE AVAILABLE

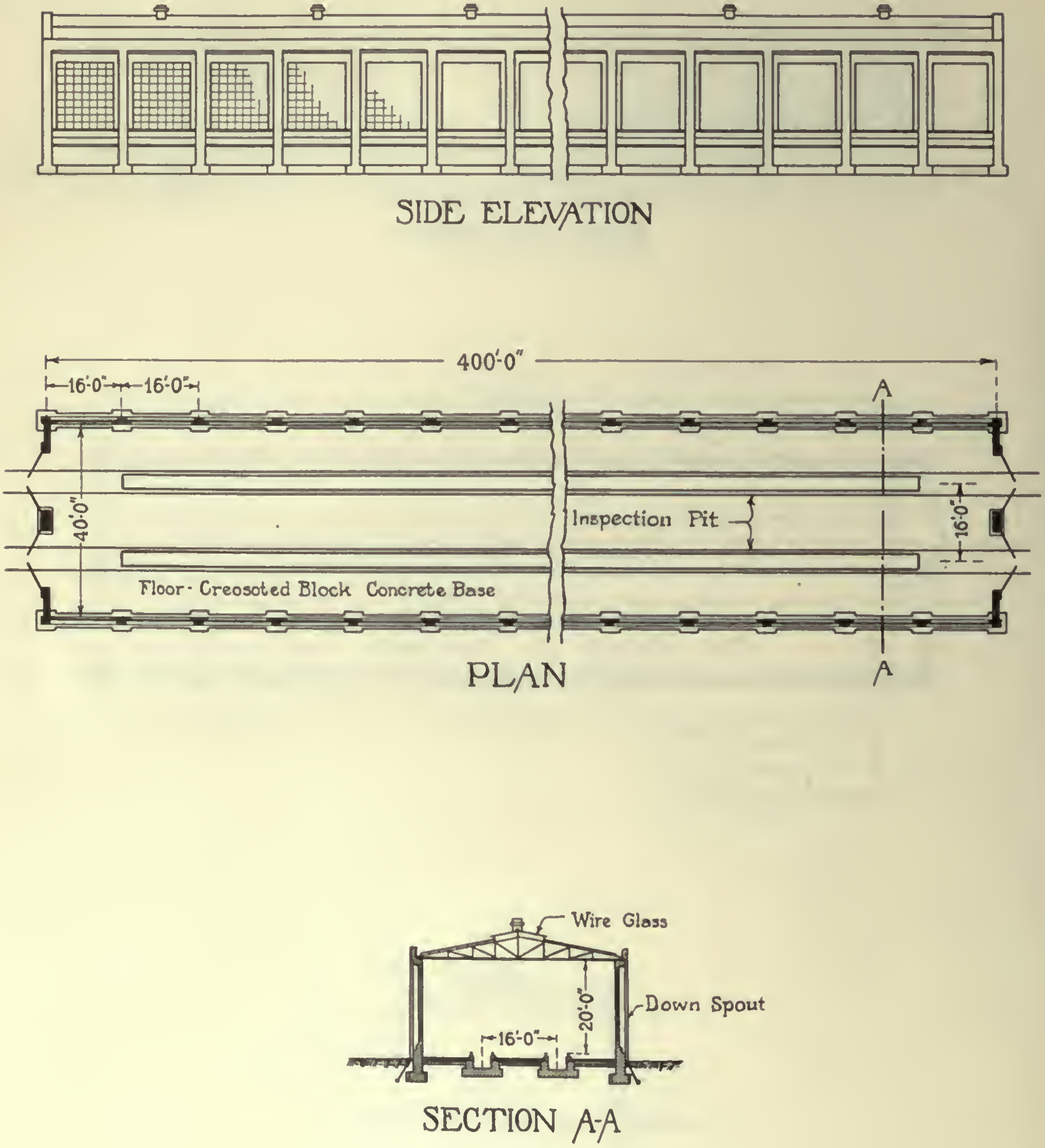
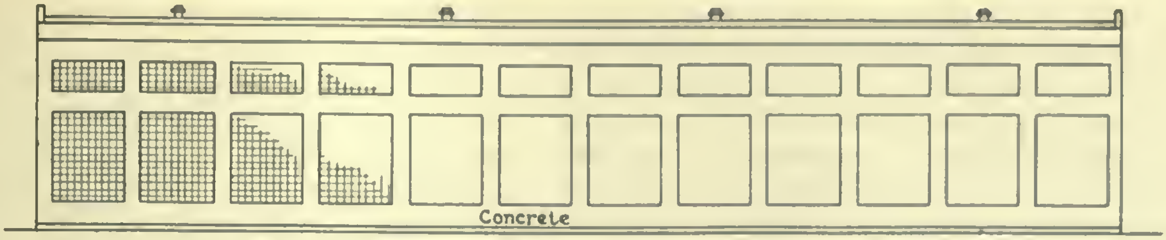
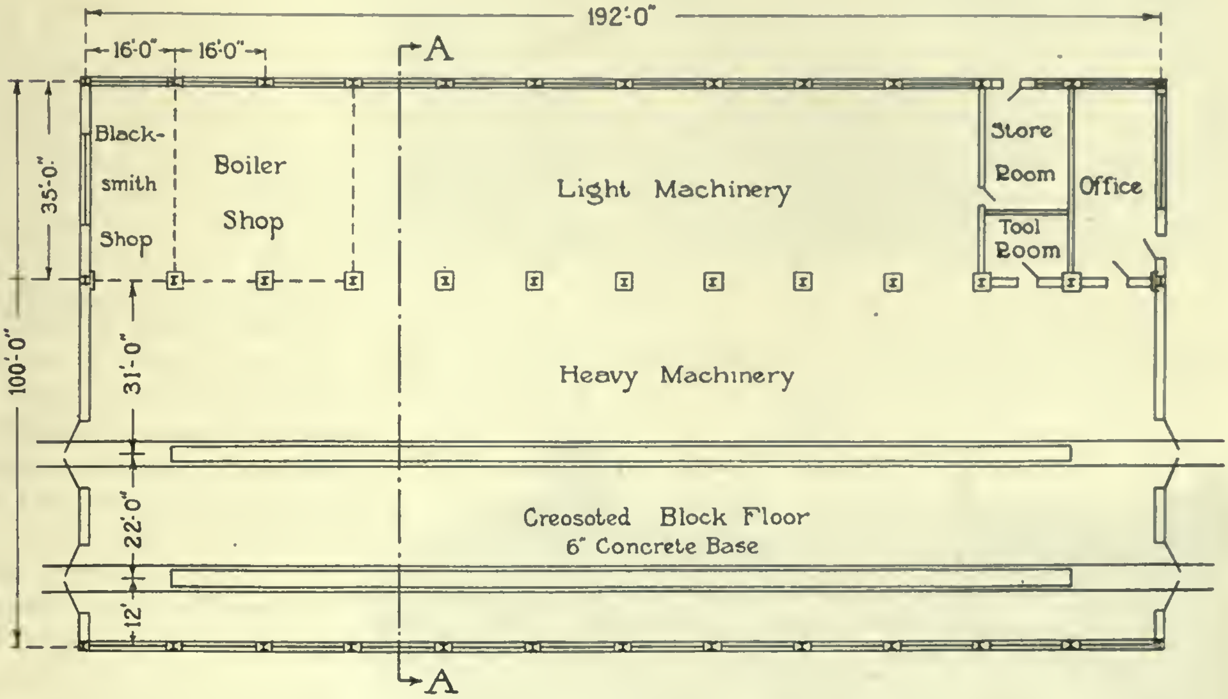


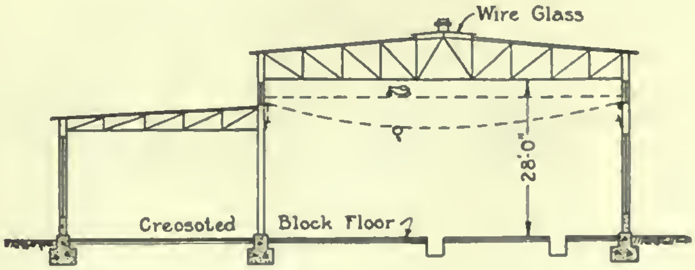
FIG. 675. STANDARD HOUSE FOR MULTIPLE-UNIT CARS



SIDE ELEVATION



PLAN



SECTION A-A

FIG. 676. STANDARD MACHINE SHOP BUILDING

the event of electrification, will be used in suburban service. This building will provide for two trains of six cars each and will ordinarily prove adequate for the requirements of roads operating light suburban service. In instances where this standard house was deemed insufficient, provision was made in the estimates for double or triple the capacity mentioned.

Fig. 676 shows plan and elevations of a standard machine shop building for use at points where new general shop facilities will be required for the care of both steam and electric locomotives. A building of this character will be required at most of the proposed transfer yards. This building is to be so constructed that a traveling crane may be installed if desired.

Standard plans have also been prepared for minor structures required and these have served as a basis for the estimates of cost.

The estimates provide also for machine shop facilities in addition to those at transfer yards, wherever such additional facilities are necessary to permit the operation of the road along lines consistent with its present practice. In other words, the standard plan has been modified to meet the specific requirements of each railroad. Thus, the Wabash Railroad, under the proposed plan of electrification, will be required to maintain yards and facilities at Clarke Junction, Ind., and at Chicago Ridge, Ill. In this case two plants will be required instead of the one plant now sufficient under steam operation. This change will have been brought about as a direct result of electrification, and the cost of the machinery required for the new plant to be established at Clarke Junction, Ind., is included as a part of the cost of electrification.

Under the plan of electrification the present locomotive terminals within the city will be eliminated except in so far as they may be remodeled to serve in connection with electric equipment. In remodeling existing locomotive terminals, it is assumed that ground now occupied by tracks and buildings used directly in handling steam locomotives will be appropriated to other useful purposes. As already noted, the buildings will, in a considerable number of cases, be made available for the care of electric locomotives. Examples of such cases are to be found in the Robey Street Yard of the Baltimore & Ohio Chicago Terminal Railroad at 14th and Robey streets, in the 40th Avenue Yard of the Chicago & North Western Railway and in the Englewood Yard of the Lake Shore & Michigan Southern Railway at 63d Street and Indiana Avenue.

FIG. 677. FACILITIES TO BE REMODELED. View of the Robey Street Yard of the Baltimore & Ohio Chicago Terminal Railroad, near 14th Place and S. Robey Street. In the proposed plan of electrification, the construction of buildings and tracks for the care of electric equipment will be required in this yard. Such construction will render necessary the remodeling of the yard.

The estimates include the cost of land for transfer yards and their related facilities for steam and electric equipment.

Views of existing yards and facilities for the care of steam locomotives which, in the event of electrification, may be remodeled or used without change for the care of electric equipment, are shown by figs. 677 to 679, inclusive. The cost of such remodeling, including any additions which may be necessary, has, in these estimates, been charged against electrification.

Related to the steam locomotive terminals are two extensive railroad repair shops. These are the Burnside shops of the Illinois Central Railroad at 95th Street and Cottage Grove Avenue, and the 40th Avenue shops of the Chicago & North Western Railway at 40th Avenue (now Crawford Avenue) and Kinzie Street. Excluding the roundhouses and their accessories, which, it is assumed, will be eliminated in the event of electrification, these facilities become merely extensive plants for the care of locomotives and cars, not differing from other repair or manufacturing plants. Hence, estimates of cost in the cases of these two roads are based upon the assumption that these plants will continue in their present operations. The exceptions are made because of the extent of the establishments. In all other cases estimates provide for the removal of shops to new locations.

FIG. 678. FACILITIES TO BE REMODELED. View in the HY Tower Yard of the Chesapeake & Ohio Railway of Indiana. Under the proposed plan of electrification, slight changes in the track and building arrangement of this yard will be required. The present engine house will remain as shown and proper buildings for electric locomotives will be added, together with the necessary tracks to accommodate the new service.

In a number of existing yards that are to become transfer points it has been found practicable to modify or extend the present arrangements so that tracks may be set aside to provide storage for trains awaiting change of motive power. Examples of such yards may be found in the Godfrey Yard of the Chicago, Milwaukee & St. Paul Railway at Mannheim, Ill.; in the Hawthorne Yard of the Illinois Central Railroad at Hawthorne, Ill.; in the Gibson Yard of the Chicago, Indiana & Southern Railroad at Gibson, Ind.; and in the Hawthorne Yard of the Chicago, Burlington & Quincy Railroad at Hawthorne, Ill.

FIG. 679. FACILITIES TO BE REMODELED. Present steam locomotive engine house of the Chicago Short Line Railway, which will be retained without change, for the care of electric locomotives.

There are 54 yards within the proposed limits of electric operation which will require some modification in track arrangement in order to meet the new conditions imposed by electrification. Of this number, 43 will require changes in order to accommodate electric locomotives or other electric equipment. The estimates include provision for the construction of 18 transfer yards at places now without yard facilities of any kind. For these yards it will be necessary to construct 338.0 miles of new track, of

TABLE CCCXXXV. COST, BY ROADS, OF PRINCIPAL BUILDINGS CHARGED TO NEW FACILITIES
(Basis of 1912)

Railroad	Coaling Stations	Electric Loco. Houses	Engine Houses	Machine Shops	Multiple-unit Equipm't Houses	Offices	Oil Houses	Power Plants	Rest Rooms	Sand Houses	Store Houses	Miscel-laneous	Total—See Table CCCXXXVI
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Atchison, Topeka & Santa Fe Ry.	$17,000	$ 34,000	$ 93,000	$ 38,000		$12,000	$ 4,000	$ 25,000	$12,000	$ 2,000	$ 5,000	$ 7,800	$ 249,800
Baltimore & Ohio R. R.	16,000	34,000	78,000	38,000		15,000	4,000	30,000	12,000	2,000	5,000	7,800	241,800
Baltimore & Ohio Chicago Terminal R. R.	13,000	26,000	24,300	23,000		4,000	1,000	8,000		1,000	1,000	1,000	102,300
Calumet, Hammond & Southeastern R. R.													
Chesapeake & Ohio Ry. of Indiana		9,000	10,800										19,800
Chicago & Alton R. R.		34,000	15,000									5,000	54,000
Chicago & Calumet River R. R.													
Chicago & Eastern Illinois R. R.		17,000	36,000				2,000	10,000				3,000	68,000
Chicago & Erie R. R.		17,000	12,000					4,500					33,500
Chicago & North Western Ry.	83,000	153,000	405,000	120,000	$210,000	40,000	16,000	140,000	32,000	11,000	17,000	12,000	1,239,000
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago		119,000		76,000	42,000								237,000
Chicago, Burlington & Quincy R. R.	25,000	51,000	120,000	38,000	50,000	18,000	6,000	50,000	12,000	4,000	5,000	4,000	383,000
Chicago Great Western R. R.	12,000	17,000	36,000	6,000		6,000	1,000	20,000		2,000	3,000	1,000	104,000
Chicago, Indiana & Southern R. R.		17,000	12,000										29,000
Chicago, Indianapolis & Louisville Ry.		17,000	21,000	6,000				5,000					49,000
Chicago Junction Ry.		34,000											34,000
Chicago, Milwaukee & St. Paul Ry.	40,000	85,000	217,600	76,000		24,000	8,000	65,000	21,000	6,000	9,000	6,000	560,600
Chicago River & Indiana R. R.													
Chicago, Rock Island & Pacific Ry.	20,000	51,000	78,000	38,000	42,000	12,000	4,000	40,000	12,000	3,000	5,000	2,000	307,000
Chicago Short Line Ry.													
Chicago Union Transfer Ry.		9,000											9,000
Chicago, West Pullman & Southern R. R.													
Elgin, Joliet & Eastern Ry.		34,000											34,000
Grand Trunk Western Ry.	12,000	17,000	75,000	38,000		12,000	4,000	40,000	12,000	3,000	5,000	3,000	221,000
Illinois Central R. R.	36,000	85,000	195,000	76,000	168,000	24,000	8,000	70,000	24,000	7,000	10,000	6,000	709,000
Illinois Northern Ry.													
Indiana Harbor Belt R. R.	500	9,000	6,000				1,000			1,000			17,500
Lake Shore & Michigan Southern Ry.	25,000	51,000	92,000	38,000	42,000	15,000	6,000	50,000	18,000	4,000	6,000	4,000	351,000
Michigan Central R. R.	12,000	17,000	50,000	38,000		12,000	3,000	25,000	8,000	3,000	4,000	2,000	174,000
Minneapolis, St. Paul & Sault Ste. Marie Ry.													
New York, Chicago & St. Louis R. R.	12,000	17,000	48,600	38,000		10,000	3,000	30,000	10,000	3,000	4,000	2,000	177,600
Pere Marquette R. R.	4,000	18,000	45,000	10,000		3,000	1,800	10,000		1,600	1,000	1,500	95,900
Pittsburgh, Cincinnati, Chicago & St. Louis Ry.	17,000	34,000	60,000	38,000		12,000	4,000	40,000	12,000	3,000	4,000	2,800	226,800
Pittsburgh, Ft. Wayne & Chicago Ry.	22,000	47,000	75,000	38,000	42,000	12,000	4,000	40,000	12,000	3,000	6,000	3,000	304,000
Pullman Railroad		9,000											9,000
Wabash Railroad	21,000	34,000	75,000	44,000		18,000	7,000	50,000	16,000	5,000	7,000	3,000	283,000
Totals	$390,500	$1,096,000	$1,880,300	$817,000	$596,000	$249,000	$87,800	$752,500	$216,000	$64,600	$97,000	$76,900	$6,323,600

TABLE CCCXXXVI. SUMMARY, BY ROADS, SHOWING COST OF NEW FACILITIES REQUIRED IN THE EVENT OF ELECTRIFICATION
(Basis of 1912)

Railroad	Cost of New Facilities																Total
	Buildings (See Table CCCXXXV)	Ash-pits	Drainage	Fire Protection	Grading	Land	Machinery	Pipe Lines, Pumps, Wells	Tanks	Water Cranes	Track	Electric Work on New Track	Turntables and Pits	Viaducts and Subways	Interlocking	Miscellaneous	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Atchison, Topeka & Santa Fe Ry	$ 249.800	$ 2,700	$ 7,000	$20,000	$ 62.500	$ 28,700	$ 40,000	$ 10,000	$ 7,000	$ 3.800	$163,525	$27,000	$ 9.000		$15.000	$ 93,975	$ 740,000
Baltimore & Ohio R. R	241,800	3.000	8.000	12,000	66.000	82,500	40,000	10.000	3,000	3.300	113,610	15,000	9,000		15.000	91.790	714.000
Baltimore & Ohio Chicago Terminal R. R	102,300	2,800	6,000	5.000	21.000	17,000	20,000	8.000	2,300	800	53,295	4.000	7,500			35.005	285,000
Calumet, Hammond & Southeastern R. R																	
Chesapeake & Ohio Ry. of Indiana	19,800	1,000			1,500	1,000					5,525	1.000				4,175	34.000
Chicago & Alton R. R	54,000			3,000	10,000	3,000	25,000				72.175	10,000			20,000	29.825	227,000
Chicago & Calumet River R. R																	
Chicago & Eastern Illinois R. R	68.000			4,000	12,000	4.000					36,600	7,000			15,000	24,400	171,000
Chicago & Erie R. R	33,500			2.000	2.500	8.000					16,875	6,000				10.125	79.000
Chicago & North Western Ry	1,239.000	27,000	23,000	76,000	201,000	196.800	270,000	156,000	24,500	14,000	555,000	99,000	36,000	$125,000		455,700	3,198.000
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	237,000			12,000			100,000				52.450					60,550	462,000
Chicago, Burlington & Quincy R. R	383.000	6,500	10.000	25.000	52.000	200.000	70.000	54,000	7.000	4,000	165,900	37,000	9,000			152,600	1,176.000
Chicago Great Western R. R	104.000	3,000	5,000	6,000	43.000	30.000	20.000	25,000	2,000	800	54.580	6,000	8,000			45,620	353.000
Chicago, Indiana & Southern R. R	29,000			2,000	6,000		10.000				12,700	6,000				9,300	75,000
Chicago, Indianapolis & Louisville Ry	49,000			3,000	2,500	2,400	10.000				13,570	4,000				13,530	98,000
Chicago Junction Ry	34,000			2,000			20.000				19,600					11,400	87.000
Chicago, Milwaukee & St. Paul Ry	560.600	9.000	12.000	33,000	101.000	67,000	105.000	106,000	10,500	6,400	372,100	61,000	26,000	60.000	50,000	237,400	1,817,000
Chicago River & Indiana R. R																	
Chicago, Rock Island & Pacific Ry	307,000	6,000	3,500	19.000	60.000	32.000	40.000	10,000	3,500	3,000	107,275	23.000	9,000			92.725	716.000
Chicago Short Line Ry																2.000	2,000
Chicago Union Transfer Ry	9,000				2.000						5,700	3,000				2.300	22.000
Chicago. West Pullman & Southern R. R																1.000	1,000
Elgin, Joliet & Eastern Ry	34.000			2.000	5.000		20.000		19,975			6,000				14.025	101.000
Grand Trunk Western Ry	221.000	2,000	7,000	13.000	70.000	40.000	40,000	34,000	5,200	3,000	157,900	25,000	9,000	60,000	15,000	105.900	808,000
Illinois Central R. R	709.000	14,000	13,000	43,000	195,000	217.000	180,000	91,000	10,500	8,000	396.065	59.000	18,000	120,000	30,000	315,435	2,419.000
Illinois Northern Ry																3.000	3.000
Indiana Harbor Belt R. R	17,500	1,000	1,000	1,000	18,000	5.000		1,000			22.400	5.000				10,100	82,000
Lake Shore & Michigan Southern Ry	351,000	10.000	7,000	22,000	297,200	17,500	50,000	35,000	7.000	4.000	223.645	47,000	9,500		20.000	165,155	1,266,000
Michigan Central R. R	174,000	1,800	6,000	11,000	75,000	40,000	30,000	25.000	3,500	3,200	155,350	26,000	8,000			84,150	643.000
Minneapolis, St. Paul & Sault Ste. Marie Ry																	
New York, Chicago & St. Louis R. R	177.600	5,000	5,000	11,000	56.000	40,000	25.000	24.000	3,500	1,200	126.800	19,000	8,000			74.900	577,000
Pere Marquette R. R	95,900	2,400	4.000	6.000	35,500	32.800	10.000	16,500	4,300	1,000	62,500	10.000	16,000			44,100	341,000
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	226,800	4,000	7.000	14,000	70,000	28,000	25,000	35,000	3,500	3,500	156,550	26,000	9,000	35,000		96,650	740,000
Pittsburgh, Fort Wayne & Chicago Ry	304,000	7,000	6.000	19,000	80,000	80.000	40.000	17,000	7,000	3,800	149,800	26,000	9,000	45,000	20,000	119.400	933,000
Pullman R. R	9,000										6,000					3,000	18.000
Wabash R. R	283,000	2,400	9,000	18,000	156,000	81,800	36.000	51,000	10.500	4,600	212.800	39,000	18.000	60.000		146,900	1,129,000
Totals	$6.323.600	$110.600	$139,500	$384,000	$1,700,700	$1.254.500	$1,226,000	$708,500	$134,775	$68,400	$3,490.290	$597,000	$218,000	$505,000	$200.000	$2,556,135	$19.617,000

which 149.4 miles will be equipped with contact system for electric operation, while the remainder, 188.6 miles, will be constructed for steam operation only.

The cost of contact system, bonding and electric work for the new trackage of the transfer yards is included in the cost of the yards.

The cost of all the principal buildings which, under the procedure described, have been determined upon and included in the estimates, is shown, by roads, in table CCCXXXV.

A summary for each railroad of the principal items that go to make up the charge against electrification because of such new facilities, including the overhead contact for new track, is presented in table CCCXXXVI. Column 2 of table CCCXXXVI shows the total of the items detailed in table CCCXXXV.

213.096 Estimated Total Cost of New Terminal Facilities: The total cost of the new terminal facilities which must be supplied if the Chicago terminals are electrified is based upon the costs of labor and material as determined for the year 1912, extended in a manner normal to these estimates (chapter 212), the factors of extension in this case being as follows:

	PER CENT
1. To cover growth in the mileage of railroads, at 3 per cent per annum for 10 years, December 31, 1912, to December 31, 1922	30 0
2. Contingencies	20.0
3. Engineering, design, supervision and administration	10.0
4. Interest, insurance and taxes during construction, at 1.75 per cent per annum for 6 years, December 31, 1916, to December 31, 1922	10.5

The values thus derived may be accepted as the estimated total costs on the basis of conditions obtaining in 1922. The estimated total cost, by railroads, of the new terminal facilities, including transfer yards, buildings and miscellaneous equipment, is set forth by table CCCXXXVII.

TABLE CCCXXXVII. ESTIMATED TOTAL COST, BY ROADS, OF NEW TERMINAL FACILITIES

(Dec. 31, 1922)

Railroad	Total Cost
1	2
Atchison, Topeka & Santa Fe Ry	$1,403,173
Baltimore & Ohio R. R	1,353,873
Baltimore & Ohio Chicago Terminal R. R	540,411
Calumet, Hammond & Southeastern R. R	....
Chesapeake & Ohio Railway of Indiana	64,470
Chicago & Alton R. R	430,433
Chicago & Calumet River R. R	....
Chicago & Eastern Illinois R. R	324,247
Chicago & Erie R. R	149,798
Chicago & North Western Ry	6,632,838
Chicago & Western Indiana R.R and the Belt Ry. of Chicago	876,035
Chicago, Burlington & Quincy R. R	2,229,908
Chicago Great Western R. R	669,352
Chicago, Indiana & Southern R. R	142,213
Chicago, Indianapolis & Louisville Ry	185,826
Chicago Junction Ry	164,968
Chicago, Milwaukee & St. Paul Ry	3,445,359
Chicago River & Indiana R. R	....
Chicago, Rock Island & Pacific Ry	1,357,665
Chicago Short Line Ry	3,792
Chicago Union Transfer Ry	41,716
Chicago, West Pullman & Southern R. R	1,896
Elgin, Joliet & Eastern Ry	191,514
Grand Trunk Western Ry	1,532,113
Illinois Central R. R	4,586,859
Illinois Northern Ry	5,689
Indiana Harbor Belt R. R	155,487
Lake Shore & Michigan Southern Ry	2,400,564
Michigan Central R. R	1,219,244
Minneapolis, St. Paul & Sault Ste Marie Ry	....
New York, Chicago & St. Louis R. R	1,094,096
Pere Marquette R. R	646,597
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	1,403,173
Pittsburgh, Ft. Wayne & Chicago Ry	1,769,136
Pullman Railroad	34,131
Wabash Railroad	2,140,787
Total	$37,197,363

ROLLING EQUIPMENT TO BE RELEASED

213.097 General Considerations: The electrification of the railroad terminals of Chicago will result in the elimination of the steam locomotive from the tracks of the city and its immediate vicinity. Locomotives thus released may be disposed of. Similarly, it is assumed that, under electrification, all suburban business which is confined to the electrified trackage will be performed by multiple-unit equipment. with the result that the cars now in this service will be released for other use. It is the purpose of the investigation reported in the present chapter to determine the amount, the first cost and the value to the railroads of all equipment thus released.

213.098 Locomotives in Through Passenger Service to be Released: As a basis for determining the number of locomotives in through passenger service to be released, the time-table of each railroad performing such service has been studied, and the number and character of schedules protected have been determined. In addition to schedule requirements, a minimum allowance of four hours at terminals has been made to provide for cleaning, inspection, replacing supplies, cleaning and starting fires, and for necessary running repairs. Upon this basis it has been shown that 350 different locomotives are now required daily in operating through passenger service between the present Chicago terminals and the first division points at which locomotives normally are changed.

The establishment of new locomotive terminals at the outer limits of electrification will shorten the run of steam locomotives and reduce the time now consumed in service by an amount equal to that now spent upon trackage which is to be electrically operated. From a study of operating conditions, it has been determined that approximately 2.5 hours per locomotive will be saved daily by the shortening of the steam locomotive runs. Time thus saved can be utilized in preparing the locomotive for the return trip or in protecting additional schedules. By assuming that each locomotive will be available for service 16 hours in each 24-hour period, the time now consumed within the proposed electric limits becomes equal to approximately 15 per cent of the available working time of the locomotive. If the flow of traffic were uniform, this would reduce the number of locomotives required by 53. The flow of traffic, however, is not uniform, the requirements between midnight and 8:00 A.M. and between 5:00 P.M. and 11:00 P.M. being much greater than between 8:00 A.M. and 5:00 P.M. A detailed analysis of schedule requirements shows that the introduction of electric operation will reduce by 37 the number of steam locomotives required to perform the through passenger service.

213.099 Locomotives in Road Freight Service to be Released: A study of the requirements of this service, as shown by the hourly flow of traffic, has been based upon reports furnished by the railroad companies. It has been determined that locomotives in freight service require a minimum time of 4 hours at terminals in preparation for the return run, and that such locomotives normally require 8 hours out of each 24 for inspection, preparation and up-keep. Basing a determination upon these facts, it is shown that there are required 244 different locomotives for daily road freight service on divisions ending in Chicago. The time consumed, per locomotive, within the proposed limits of electrification is approximately 2.5 hours and the average total time in service for these locomotives is approximately 14.5 hours per day. If the flow of traffic were uniform, the introduction of electric operation under the plans set forth by the Committee would release 42 locomotives in this service, but under conditions imposed by existing schedules the number released will be 20.

213.100 Locomotives and Coaches in Suburban Passenger Service to be Released: All equipment in that portion of suburban passenger service which is confined to the proposed limits of electrification will be released. Information furnished in detail by the railroads regarding the extent and character of this equipment shows that the number of locomotives to be released is 151 and that the number of suburban passenger coaches to be released is 742.

213.101 Locomotives in Yard Service, Including Freight and Passenger Transfer, to be Released: The traffic flow, as measured in locomotive-hours, in this service has been determined from reports furnished by the railroads. It has been assumed that a steam locomotive in yard and transfer service is available for use for 16 hours in each 24-hour period. Diagrams have been prepared showing the number of locomotives required in this service by each road during each hour of the day. From these diagrams the number of locomotives required to perform the whole service of the road has been determined. An illustration of a typical diagram is presented as fig. 680.

The diagram shows that between midnight and 1:00 A.M. there were required 58 locomotives to perform the service. The upper portion of the diagram indicates that the service during this hour was supplied by 30 locomotives, which began work at midnight and continued in service until 4:00 P.M.; by 20 locomotives, which began work at 4:00 o'clock the previous afternoon and continued in service until 8:00 A.M.; by 1 locomotive, which was ready for service at 2:00 o'clock the previous afternoon, worked intermittently until midnight and went out of service at 6:00 A.M.; by 2 locomotives, which began work at 2:00 P.M. the previous day, worked intermittently during the afternoon and went out of service at 6:00 A.M.; and by 5 locomotives (2 and 3 by the diagram), which began work at 9:00 o'clock the preceding morning and went out of service at 1:00 A.M. Thus it is shown that 58 locomotives were in service from the hour of 12:00 midnight to 1:00 A.M.

To the number of locomotives thus determined, an addition of approximately 10 per cent has been made to cover units out of service and to provide for exigencies, the actual addition, as shown by a summarization of the results for all roads, amounting to 8.5 per cent.

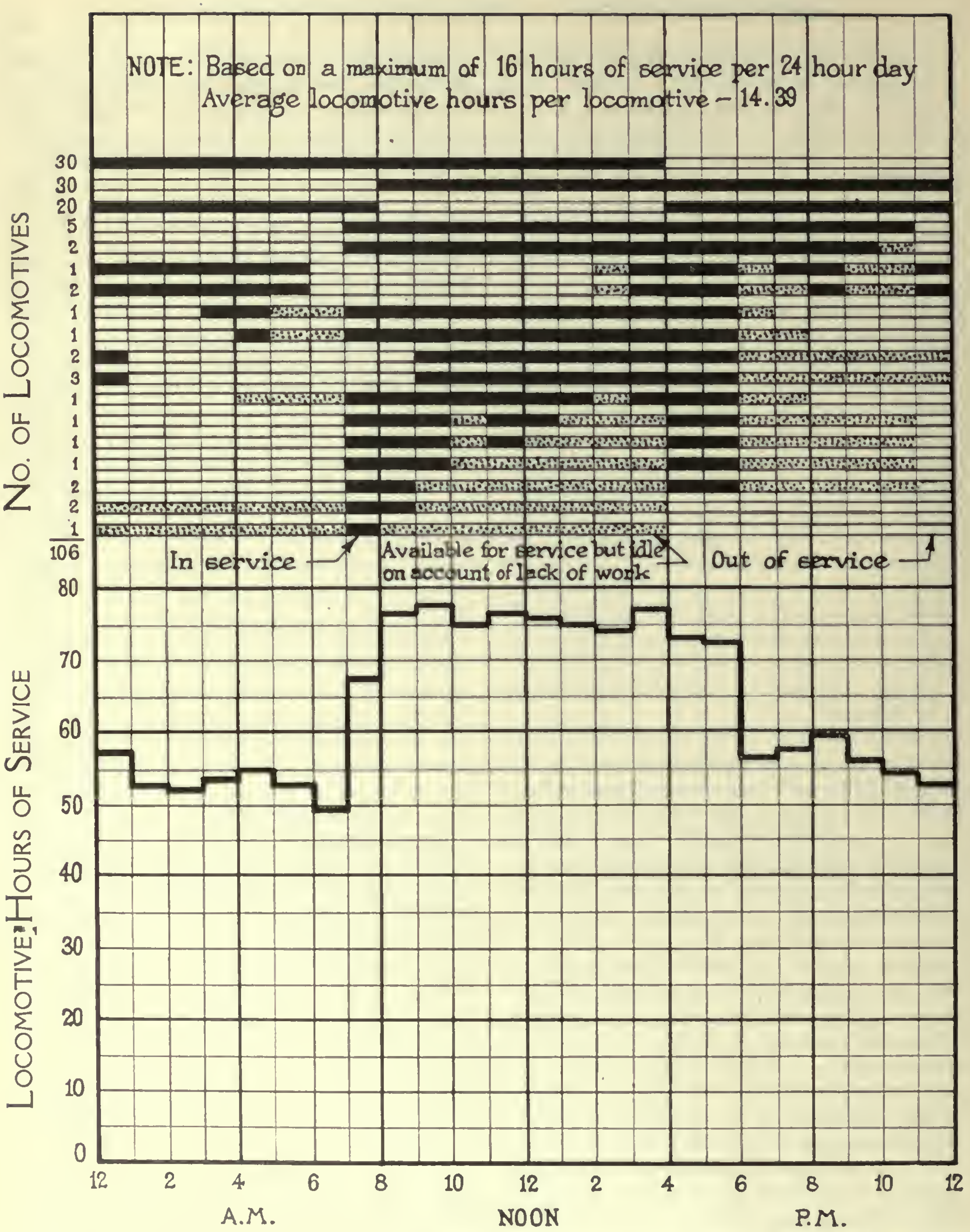


FIG. 680. NUMBER OF STEAM LOCOMOTIVE-HOURS OF SERVICE AND NUMBER OF STEAM LOCOMOTIVES REQUIRED TO PERFORM THE YARD, FREIGHT TRANSFER AND PASSENGER TRANSFER SERVICES OF THE CHICAGO & NORTH WESTERN RAILWAY

By this process it has been determined that, on tracks to be electrified, 140 locomotives are now required for transfer service and 612 for yard service, all of which will be released.

213.102 Summary of Rolling Equipment to be Released: Summarizing the preceding statements, the effect of electrification, if carried out under the plans outlined, will be to release from service rolling equipment to the extent indicated, by services, in table CCCXXXVIII.

TABLE CCCXXXVIII. SUMMARY OF RELEASED ROLLING EQUIPMENT, BY SERVICES
(Basis of 1912)

Item	No.
Through passenger locomotives	37
Road freight locomotives	20
Suburban passenger locomotives	151
Freight and passenger transfer locomotives	140
Yard locomotives	612
Suburban passenger coaches	742

213.103 First Cost of Locomotives to be Released: The locomotive equipment of the several roads now performing the service of the Chicago terminals varies greatly in character. It was found impracticable to select from among the locomotives now in service those which would be released in the event of electrification. A determination of the number released does not in itself fix the type. In approaching this problem, therefore, no attempt has been made to individualize locomotives. The process adopted has been that of reducing the characteristics of all locomotives now employed in a given service to those of the average locomotive employed in that service. For example, the average weight of all locomotives now performing a given service in the Chicago terminals is assumed to be the weight of the typical locomotive in that service. The weight of the typical locomotive for each of the five classes of locomotives involved is set forth by table CCCXXXIX.

TABLE CCCXXXIX. WEIGHT OF TYPICAL STEAM LOCOMOTIVES IN DIFFERENT SERVICES
(Basis of 1912)

Service	Average Weight on Drivers Lb.	Average Total Weight Lb.
Through passenger locomotives	144,000	314,000
Road freight locomotives	160,000	324,000
Transfer locomotives	160,000	324,000
Yard locomotives	135,000	268,000
Suburban passenger locomotives	91,000	222,000

By this process, it is assumed that all roads are performing a given service with locomotives the average of which will be represented by the type defined. The widest departure from the facts which this assumption involves is in the case of suburban passenger service. In this service certain roads use locomotives which are lighter, and certain other roads locomotives which are heavier, than the typical locomotives. Estimates of cost, therefore, based on the typical locomotives, will result in an overestimate of the value of suburban locomotives for certain roads and an underestimate for others, but the results for the whole terminal will be substantially correct.

Estimates of the first cost of locomotives possessing the characteristics which have been set forth, were made up after consultation with locomotive builders. These are presented by table CCCXL.

TABLE CCCXL. ESTIMATED FIRST COSTS OF TYPICAL STEAM LOCOMOTIVES FOR DIFFERENT SERVICES
(Basis of 1912)

Service	Cost
Through passenger locomotives	$18,500
Road freight locomotives	18,500
Transfer locomotives	15,500
Yard locomotives	13,000
Suburban passenger locomotives	12,500

213.104 First Cost of Passenger Coaches to be Released: The number of suburban passenger coaches to be released in the event of electrification having been determined (section 213.102), their first cost has been estimated from statistics furnished by the owning roads or from quotations supplied by builders of such equipment, the latter being accepted as representing the cost, under present-day conditions, of new cars of the same general type as those now existing. The values supplied by the railroad companies were generally in excess of those given by the car builders. A review of all the facts resulted in fixing the first cost of the average coach now used in suburban passenger service at $5,200.

213.105 Total Amount of Initial Investment in Locomotives and Coaches to be Released: The estimated first cost of locomotives and coaches to be released in the event of electrification has been determined, by roads, upon the basis of the unit first costs and the number of locomotives and coaches of each class to be released by each road (section 213.102). The values thus derived represent the estimated first cost of such equipment by roads on the basis of the conditions existing in 1912. These values are set forth in table CCCXLI.

TABLE CCCXLI. ESTIMATED FIRST COST OF ROLLING EQUIPMENT TO BE RELEASED, BY ROADS

(Basis of 1912)

Railroad	First Cost
Atchison, Topeka & Santa Fe Ry	$ 260,500
Baltimore & Ohio R. R	206,000
Baltimore & Ohio Chicago Terminal R. R	393,000
Calumet, Hammond & Southeastern R. R	39,000
Chesapeake & Ohio Ry. of Indiana	46,500
Chicago & Alton R. R	249,500
Chicago & Calumet River R. R	52,000
Chicago & Eastern Illinois R. R	158,500
Chicago & Erie R. R	49,500
Chicago & North Western Ry	3,936,000
Chicago & Western Indiana R.R. and the Belt Ry. of Chicago	881,500
Chicago, Burlington & Quincy R. R	1,249,000
Chicago Great Western R. R	122,000
Chicago, Indiana & Southern R. R	18,500
Chicago, Indianapolis & Louisville Ry	88,500
Chicago Junction Ry	650,000
Chicago, Milwaukee & St. Paul Ry	1,320,800
Chicago River & Indiana R. R.*	....
Chicago, Rock Island & Pacific Ry	1,005,400
Chicago Short Line Ry	26,000
Chicago Union Transfer Ry †	....
Chicago, West Pullman & Southern R. R	130,000
Elgin, Joliet & Eastern Ry	571,500
Grand Trunk Western Ry	133,000
Illinois Central R. R	1,678,800
Illinois Northern Ry	91,000
Indiana Harbor Belt R. R	91,000
Lake Shore & Michigan Southern Ry	928,100
Michigan Central R. R	333,000
Minneapolis, St. Paul & Sault Ste. Marie Ry	104,000
New York, Chicago & St. Louis R. R	216,000
Pere Marquette R. R	124,500
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	554,000
Pittsburgh, Fort Wayne & Chicago Ry	839,300
Pullman Railroad	65,000
Wabash Railroad	315,000
Total	$16,926,400

* Included in the Chicago Junction Ry.
† Included in the Chicago & Western Indiana R. R.

The estimated first cost of rolling equipment to be released, segregated by classes of equipment, is shown by table CCCXLII.

TABLE CCCXLII. TOTAL FIRST COST OF ROLLING EQUIPMENT TO BE RELEASED, BY CLASSES OF EQUIPMENT

(Basis of 1912)

Class of Equipment	No.	Unit Cost	Total Cost
1	2	3	4
Through passenger locomotives	37	$18,500	$ 684,500
Road freight locomotives	20	18,500	370,000
Transfer locomotives	140	15,500	2,170,000
Yard locomotives	612	13,000	7,956,000
Suburban passenger locomotives	151	12,500	1,887,500
Suburban passenger coaches	742	5,200	3,858,400
Total			$16,926,400

The number of locomotives and coaches to be released will increase as the business of the terminals increases. The estimates of the first cost of released rolling equipment have been extended in the manner normal to these estimates (chapter 212), the factor of extension in this case being as follows:

	PER CENT
To cover growth at 3 per cent per annum for 7 years, December 31, 1912, to December 31, 1919	21 0

In the change from steam to electric operation under the plans of the Committee, it is assumed that the change of motive power will be made gradually as certain railroads or certain services of individual roads become equipped for the reception of the new method of operation. Some of the changes will be made early in the construction period; others, not until the completion of the entire work. For this reason, it is assumed that no new steam equipment will be required after the end of the year 1919.

The values thus derived may be accepted as the estimated first cost of the rolling equipment to be released in 1922. These estimates are set forth, by roads, in table CCCXLIII

TABLE CCCXLIII. ESTIMATED FIRST COST OF ROLLING EQUIPMENT TO BE RELEASED, BY ROADS

(Dec. 31, 1922)

Railroad	First Cost
Atchison, Topeka & Santa Fe Ry	$ 315,205
Baltimore & Ohio R. R	249,260
Baltimore & Ohio Chicago Terminal R. R	475,530
Calumet, Hammond & Southeastern R. R	47,190
Chesapeake & Ohio Ry. of Indiana	56,265
Chicago & Alton R. R	301,895
Chicago & Calumet River R. R	62,920
Chicago & Eastern Illinois R. R	191,785
Chicago & Erie R. R	59,895
Chicago & North Western Ry	4,762,560
Chicago & Western Indiana R. R. and the Belt Ry of Chicago	1,066,615
Chicago, Burlington & Quincy R. R	1,511,290
Chicago Great Western R. R	147,620
Chicago, Indiana & Southern R. R	22,385
Chicago, Indianapolis & Louisville Ry	107,085
Chicago Junction Ry	786,500
Chicago, Milwaukee & St. Paul Ry	1,598,168
Chicago River & Indiana R. R *	....
Chicago, Rock Island & Pacific Ry	1,216,534
Chicago Short Line Ry	31,460
Chicago Union Transfer Ry †	....
Chicago, West Pullman & Southern R. R	157,300
Elgin, Joliet & Eastern Ry	691,515
Grand Trunk Western Ry	160,930
Illinois Central R. R	2,031,348
Illinois Northern Ry	110,110
Indiana Harbor Belt R. R	110,110
Lake Shore & Michigan Southern Ry	1,123,001
Michigan Central R. R	402,930
Minneapolis, St. Paul & Sault Ste. Marie Ry	125,840
New York, Chicago & St. Louis R. R	261,360
Pere Marquette R. R	150,645
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	670,340
Pittsburgh, Fort Wayne & Chicago Ry	1,015,553
Pullman Railroad	78,650
Wabash Railroad	381,150
Total	$20,480,944

* Included in the Chicago Junction Ry.
† Included in the Chicago & Western Indiana R. R.

213.106 Estimated Release Value of Locomotives: In determining the release value of locomotives the problem was approached from several points of view:

1. Dealers in second-hand locomotives were consulted and estimates were made of the present selling value of the typical locomotives involved.

2. The owning railroads were requested to furnish a statement of present values.

3. An estimate was made on the basis of first cost less a 4 per cent annual depreciation charge, assuming that all locomotives, except road freight and suburban locomotives, were 10 years old, that the road freight locomotives were 9 years old and that the suburban passenger locomotives were 15 years old, these assumptions being fairly representative of the facts.

In analyzing results thus determined, it was found that estimates submitted by second-hand dealers were based entirely upon the demand for such equipment; that there was little demand for second-hand passenger locomotives and practically none for suburban passenger locomotives, while switching and freight locomotives were more readily salable. The estimates of the railroad companies represented present values based upon various systems of accounting. An estimate based upon first cost, 4 per cent depreciation and an assumed age, gave results generally lower than those quoted by the railroads and much higher than those proposed by the dealers in second-hand materials. It is clear that some of the equipment will have little more than scrap value, while other equipment will be capable of performing elsewhere the highest class of service required in steam railroad operation. Taking all the facts into account, unit release values have been determined as presented by table CCCXLIV.

TABLE CCCXLIV. ESTIMATED UNIT RELEASE VALUES OF LOCOMOTIVES IN DIFFERENT SERVICES

(Basis of 1912)

Service	Estimated Unit Release Value
Through passenger locomotives	$11,000
Road freight locomotives	12,000
Transfer locomotives	9,300
Yard locomotives	7,800
Suburban passenger locomotives	5,000

213.107 Estimated Release Value of Coaches: The release value of coaches in suburban passenger service on the Chicago terminals was determined by a process similar to that employed in determining the release value of locomotives. Many of the cars used in this service are old, on the average not far from 20 years. A road performing important suburban service has cars, the first cost of which averaged $5,318, which value, in the process of accounting, has been depreciated to $4,183. It is believed that if these cars were taken out of their present service they would not be suitable for use elsewhere. If sold or scrapped they would bring an average return of approximately $400 per car. Another road estimates the value of its suburban cars, if taken from existing service, as low as $735. The chief difficulty in disposing of equipment of this class arises from the fact that much of it is too light for general use in trains with other equipment. It is serviceable only when it can be segregated. Taking all the facts into account, it has been assumed that $500 per car represents a fair average release value for such equipment.

213.108 Total Estimated Release Value of Locomotives and Cars: The estimated release value of locomotives and cars was determined, by roads, upon the basis of the unit release values and the number of locomotives and cars of each class to be released by each road (section 213.102). The values thus derived represent the estimated release value of such equipment on the basis of the conditions existing in 1912. These values are set forth in table CCCXLV.

TABLE CCCXLV. ESTIMATED RELEASE VALUE OF ROLLING EQUIPMENT, BY ROADS

(Basis of 1912)

Railroad	Release Value
Atchison, Topeka & Santa Fe Ry	$ 158,000
Baltimore & Ohio R. R	125,300
Baltimore & Ohio Chicago Terminal R. R	235,500
Calumet, Hammond & Southeastern R. R	23,400
Chesapeake & Ohio Ry. of Indiana	27,900
Chicago & Alton R. R	149,600
Chicago & Calumet River R. R	31,200
Chicago & Eastern Illinois R. R	95,000
Chicago & Erie R. R	29,600
Chicago & North Western Ry	1,402,000
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	437,800
Chicago, Burlington & Quincy R. R	443,200
Chicago Great Western R. R	73,200
Chicago, Indiana & Southern R. R	12,000
Chicago, Indianapolis & Louisville Ry	53,000
Chicago Junction Ry	390,000
Chicago, Milwaukee & St. Paul Ry	761,100
Chicago River & Indiana R. R.*	......
Chicago, Rock Island & Pacific Ry	331,000
Chicago Short Line Ry	15,600
Chicago Union Transfer Ry †	......
Chicago, West Pullman & Southern R. R	78,000
Elgin, Joliet & Eastern Ry	342,900
Grand Trunk Western Ry	79,600
Illinois Central R. R	586,200
Illinois Northern Ry	54,600
Indiana Harbor Belt R. R	54,600
Lake Shore & Michigan Southern Ry	389,600
Michigan Central R. R	199,600
Minneapolis, St. Paul & Sault Ste. Marie Ry	62,300
New York, Chicago & St. Louis R. R	130,400
Pere Marquette R. R	74,700
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	334,100
Pittsburgh, Fort Wayne & Chicago Ry	437,900
Pullman Railroad	39,000
Wabash Railroad	190,700
Total	$7,848,600

* Included in the estimates for the Chicago Junction Ry.
† Included in the estimates for the Chicago & Western Indiana R. R.

The estimated release value of rolling equipment, segregated by classes of equipment, is shown by table CCCXLVI.

TABLE CCCXLVI. RELEASE VALUE OF ROLLING EQUIPMENT, BY CLASSES

(Basis of 1912)

Equipment	No.	Unit Value	Total
1	2	3	4
Through passenger locomotives	37	$11,000	$ 407,000
Road freight locomotives	20	12,000	240,000
Transfer locomotives	140	9,300	1,302,000
Yard locomotives	612	7,800	4,773,600
Suburban passenger locomotives	151	5,000	755,000
Suburban passenger cars	742	500	371,000
Total			$7,848,600

The number of locomotives and cars to be released will increase as the business of the terminals increases. The estimates of release value of rolling equipment have been extended in a manner normal to these estimates (section 212), the factor of extension in this case being as follows:

	PER CENT
To cover growth, at 3 per cent per annum for 7 years, December 31, 1912, to December 31, 1919	21.0

The values thus derived may be accepted as the estimated release value of the rolling equipment involved, in 1922. These estimates are set forth by roads in table CCCXLVII.

A SUMMARY OF THE PRECEDING SECTIONS RELATING TO INSTALLATION COSTS

213.109 The Items of Cost: The several items under which the cost of electrification has been set forth are given in table CCCXLVIII. These values are subject to limitations which, while already set forth in detail, may be briefly reviewed here. They cover the equipment necessary for the electric operation of a definite extent of trackage and traffic, and the requirements incident to the growth in the extent of this trackage and traffic up to December 31, 1922. They include only such changes in the facilities existing in 1912 as are essential to the admission of the new equipment and the new operating procedure, and they are based upon the assumption that the facilities for the generation and transmission of electric energy will be developed as a single system for the joint use of all roads. There is, however, nothing in the plan which requires the joint operation of trains or the joint use of tracks to a greater extent than at present.

TABLE CCCXLVII. ESTIMATED RELEASE VALUE OF ROLLING EQUIPMENT, BY ROADS, WHICH WILL BE DISPLACED IN THE EVENT OF ELECTRIFICATION

(Dec. 31, 1922)

Railroad	Release Value
Atchison, Topeka & Santa Fe Ry	$ 191,180
Baltimore & Ohio R. R	151,613
Baltimore & Ohio Chicago Terminal R. R	284,955
Calumet, Hammond & Southeastern R. R	28,314
Chesapeake & Ohio Ry. of Indiana	33,759
Chicago & Alton R. R	181,016
Chicago & Calumet River R. R	37,752
Chicago & Eastern Illinois R. R	114,950
Chicago & Erie R. R	35,816
Chicago & North Western Ry	1,696,420
Chicago & Western Indiana R. R and the Belt Ry. of Chicago	529,738
Chicago, Burlington & Quincy R. R	536,272
Chicago Great Western R. R	88,572
Chicago, Indiana & Southern R. R	14,520
Chicago, Indianapolis & Louisville Ry	64,130
Chicago Junction Ry	471,900
Chicago, Milwaukee & St. Paul Ry	920,931
Chicago River & Indiana R. R.*	....
Chicago, Rock Island & Pacific Ry	400,510
Chicago Short Line Ry	18,876
Chicago Union Transfer Ry †	......
Chicago, West Pullman & Southern R. R	94,380
Elgin, Joliet & Eastern Ry	414,909
Grand Trunk Western Ry	96,316
Illinois Central R. R	709,302
Illinois Northern Ry	66,066
Indiana Harbor Belt R. R	66,066
Lake Shore & Michigan Southern Ry	471,416
Michigan Central R. R	241,516
Minneapolis, St. Paul & Sault Ste. Marie Ry	75,383
New York, Chicago & St. Louis R. R	157,781
Pere Marquette R. R	90,387
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	404,261
Pittsburgh, Fort Wayne & Chicago Ry	529,859
Pullman Railroad	47,190
Wabash Railroad	230,747
Total	$9,496,806

* Included in the Chicago Junction Ry.

† Included in the Chicago & Western Indiana R. R.

The values given do not cover any general revision of the railroad terminal establishment as it existed in 1912. The basis thus defined, underlying the values presented in table CCCXLVIII, may be accepted as that of minimum cost. If it should transpire that, in the later development of the problem, the plan outlined should prove unsatisfactory, and if the electrification of Chicago's railroad terminals should proceed as a series of individual undertakings, each covering the requirements of a single road, the service of the terminal would involve lower load factors, requiring greater total capacity of generating and transmission equipment and, consequently, greater costs for these items than those set forth by table CCCXLVIII.

The items presented in table CCCXLVIII cover the installation cost of a 2,400-volt direct current system and of an 11,000-volt alternating current system. The cost of a 600-volt direct current system (third rail), and a summary of costs for the three different systems of electrification, will be hereinafter set forth (section 213.137).

TABLE CCCXLVIII. SUMMARY OF ITEMS COVERING INSTALLATION COSTS INCIDENT TO THE ELECTRIFICATION OF THE CHICAGO RAILROAD TERMINALS

(Dec. 31, 1922)

Item	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3
Power station	$10,213,458	$10,302,104
Transmission system	1,305,444	1,618,693
Substations	5,660,352	2,024,736
Switching stations	1,522,285	573,073
Overhead contact system	33,895,276	28,141,188
Bridge warnings	1,071,989	1,071,989
Return circuit	6,069,899	4,446,033
Prevention of inductive effects and electrolysis	0	996,727
Telephone system	272,052	272,052
Electric locomotives, multiple-unit equipment, work and inspection equipment	84,003,395	91,703,557
Spare parts	502,725	485,343
Changes in overhead structures	834,261	834,261
Changes in wire lines	2,028,007	2,028,007
Changes in signal systems	6,993,919	6,111,407
Removal and re-establishment of steam locomotive terminals:		
a. Cost of transferring machinery ... $96,383		
b. New steam locomotive terminals and transfer yards $37,197,363	37,293,746	37,293,746
Totals	$191,666,808	$187,902,916

THE INDETERMINATE COSTS OF ELECTRIFICATION

213.110 Capital Requirements as Affected by Modifications of the Committee's Plan: The Committee's estimates of cost as already presented are based upon a definite program of procedure (chapter 212). The estimates may be expected to work out in practice only in so far as the procedure assumed is followed. The procedure has been designedly chosen to give results which may be accepted as those of minimum cost.

213.111 Capital Requirements as Affected by the Extent of the Plan: In determining the extent of trackage to be electrified, the Committee's plan (section 209.10) has been based upon the conception that electrification is proposed as a means in smoke abatement. The plan provides for the electrification of all tracks within the city and the termination of such electrification as soon as practicable beyond the limits of the city; it gives due consideration to existing operating requirements, but it is nevertheless a minimum plan.

The railroad official who reviews the work of the Committee will probably feel that, if electrification is imposed, the extent of trackage affected should be determined from considerations which are the outgrowth of operating conditions, whereas the Committee has sought to deal with the minimum trackage consistent with reasonable operating requirements. The two views are not necessarily antagonistic. Their existence, however, may prevent perfect agreement with reference to many matters of detail.

For example, in fixing the limits to be observed by the Chicago, Burlington & Quincy Railroad, the Committee has specified complete electrification to a point (Hawthorne) 6.8 miles from the Union Station, and partial electrification to provide for suburban service only to a point (Downers Grove) which is 21.3 miles from the Union Station. There are eight daily suburban trains each way passing through this outer point, and under the Committee's plan these trains will change locomotives at the transfer point. In reviewing the work of the Committee, the officers of this road have reached the conclusion that, if they were required to electrify, they would provide for the electric operation of freight service to a point (Eola) 33.4 miles from Chicago and for suburban service to a point (Aurora) 37.4 miles from the Union Station. That is, the officials of the road believe it would be impracticable to electrify unless they were to proceed by a plan far more comprehensive than that which has formed the basis of the Committee's estimates of costs. Again, the Committee's plan provides an overhead contact system sufficient for existing tracks. The officials of the railroad assume that parts of their route will soon require additional tracks, and if they were to electrify they would make the cross-span of their overhead structures sufficient to provide for these anticipated additions to the existing establishment.

Similarly, the officials of the Pennsylvania Lines West of Pittsburgh believe it is necessary, in the event of electrification, to extend the main track electrification of the Pittsburgh, Fort Wayne & Chicago Railway to Hobart, Ind., 33.1 miles from the Union Station and approximately 10 miles beyond Clarke, Ind., the limit fixed by the Committee's plan. The management feels also that electrification will require the separation of grades wherever their lines are crossed by trolley lines of traction companies. This will require the elevation of their tracks through Gary, Ind.

For the Chicago & North Western Railway, the Committee's plan provides for electrification to Waukegan, Niles Center, Desplaines and Elmhurst. The officers of the road report, as a result of their study of the Committee's plan, that in the event of electrification they would prefer to make material extensions of this plan, namely, to electrify from Niles Center to Lake Bluff, 19.6 miles, from Desplaines to Crystal Lake, 26.3 miles, and from Elmhurst to West Chicago, 14.2 miles, and also to construct and electrify two additional tracks between Elmhurst and West Chicago.

It is evident, therefore, that, if electrification should be entered upon by any individual road or by all the roads entering the city of Chicago, some one, or all, would elect to extend electric operation beyond the limits which have been fixed by the Committee, and that by so doing their installation costs would be larger than those estimated by the Committee.

213.112 Capital Requirements as Affected by Terminal Changes: The Committee's estimates are based upon the railroad establishment of 1912 and are extended to cover growth to 1922. The factor of extension is based upon a normal development of the activities which characterized the railroad establishment of 1912. As a matter of fact, the terminals of Chicago are taking on new forms and the activities are assuming new aspects, the effect of which, while indeterminate so far as many of the processes of the Committee are concerned, will nevertheless require an extension of the limits of electrification. For example, the large classification yard at Clearing, lying entirely outside of the city limits, might, in the opinion of the Committee, easily be assumed to be beyond the limits of electrification. It was therefore excluded from consideration. In the latter part of the Committee's statistical year, 1912, however, this yard was acquired by the Belt Railway of Chicago, and subsequently this road proceeded with the development, on a large scale, of improvements and extensions of the yard which greatly increased the significance of the trackage involved. Under plans which will soon become effective, trains which in the event of electrification will be drawn by electric locomotives, will arrive at and depart from this yard. For the accommodation of this traffic approximately 75 miles of trackage must be electrified. Thus, operating conditions which have arisen subsequent to the Committee's statistical year have so changed the character of a great freight terminal as to require some extension in the limits to be observed for electrification. Other terminal changes are imminent in Chicago, and it is not improbable that each one as it comes will have some effect upon the extent of the problem of electrification. It is not unlikely that some of these changes will make necessary an extension in the limits to be observed in such work. The extent to which such consideration will enter into the problem must for the present purpose remain indeterminate.

213.113 Capital Costs as Affected by the Joint Use of Facilities: The fact must be recognized that in the development of railroad facilities, under conditions which involve the interests of many different corporations, it is not always feasible nor expedient to determine the value of a procedure by considering engineering efficiency alone. Other factors enter. Railroads, as a rule, are disinclined to combine for the purpose of operating jointly any facility where their purposes can be served through individual operation. The chance that interruptions of service or other complications incident to one road may, through the existence of a joint facility, affect the operations of another is a matter which is regarded by many railroad officials as of far greater importance than the possible saving in operating and maintenance expenses arising from the use of a joint facility.

The Committee, on the other hand, has assumed that among the advantages to be derived from electrification are those which will permit the joint use of certain facilities introduced by the change. Its estimates of the cost of electrification are based upon the assumption that the power station, the transmission system, the substations and the switching stations will be developed as a single system for the joint use of all railroads. If, in the actual working out of the problem, individual railroads should, for such considerations as have been set forth or for other reasons, insist upon the development of individual power stations, switching stations and substations, the cost to the individual road and the combined total cost of electrifying the railroad terminals of Chicago would be materially in excess of the costs estimated by the Committee. For example, the Committee has assigned to the Chicago & North Western Railway a power station cost of $2,210,831.* This is the railroad's portion of

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* This cost and all other electrification costs which follow in this section are for the 11,000-volt alternating current system.

the total cost of a power station designed to meet the requirements of the entire terminal. The amount is based upon the power requirements of the Chicago & North Western Railway as compared with the total power requirements of the terminal. The railroad itself, however, in examining this question assumes at once that, if it should electrify, it would prefer an individual power station, and its estimate of the cost of the individual facility is $3,894,767. The difference, $1,683,936, is the amount in excess of the Committee's estimates which the railroad would feel it ought to pay to secure independence in this respect.

The development of individual transmission lines and, in some cases, of individual substations by different railroads, where the Committee's estimates are based upon the joint use of such facilities, will tend to increase the total cost of electrification. The total cost, as estimated by the Committee, of those facilities (power station, transmission lines, substations and switching stations) which are designed for joint use amounts to $14,518,606. Any assumption by the railroads to the effect that the larger roads must have individual facilities, and that the smaller roads must be grouped with the larger roads, will materially increase this item of cost.

213.114 Capital Requirements as Affected by Precipitated Costs: By far the most important factors in the sum total of indeterminate costs will be those arising from improvements only remotely related to electrification, but which will be precipitated by a decision to electrify. Thus, most railroads are looking forward to betterments involving large expenditures to be undertaken in future years. Under normal conditions, certain items in their program may not need to be carried out for another decade, but under conditions introduced by a decision to electrify, these may require attention prior to, or coincident with, electrification.

One effect, therefore, of electrification will be to advance any program for betterments, and by so doing to increase the capital requirements at the time of electrification far beyond the limits which would be required for electrification alone.

A few illustrations of the manner in which precipitated costs arise will suffice to show their importance. The introduction of electric traction would involve changes in automatic signals which are now controlled by direct current track circuits. Such signals must be re-equipped in order that they may be controlled by current which is not affected by the return propulsion current in the track. This is a considerable item and the Committee's estimates are designed to cover it. It is, however, altogether likely that some roads would prefer a complete replacement of existing signals by new signals to the reconstruction of those which they now have. Such a procedure would not only provide for the substitution of modern equipment for that which is more or less antiquated, but it would permit a redistribution or spacing to meet the changed conditions of traffic with which the roads are already confronted. The cost of a complete renewal of signals would be much in excess of the Committee's estimates. It represents an item of expense which, except for the imminence of electrification, would not be entered upon for many years, but which, in the judgment of those responsible, becomes unavoidable as a preliminary to electrification.

In commenting upon this aspect of the Committee's work, a representative of the Chicago, Rock Island & Pacific Railway writes that, "The Chicago terminals have hardly kept pace with the requirements of modern railway terminals, and while they can continue to give satisfactory service for steam operation they are not in shape to meet the advent of electrification without an almost entire rebuilding for their entire length, about 30 miles."

An officer of the Grand Trunk Western Railway writes, "In existing yards and at junction points there would be required, at the time of electrification, a general remodeling and improvement of existing track installations, the substitution of heavier rails, frogs, switches, etc., in order that the electric improvements would be performed upon a permanent basis of track arrangement and construction." The cost of these improvements would be precipitated by electrification.

The Baltimore & Ohio Chicago Terminal Railroad expresses the opinion that the electrification of its lines would necessitate the separation of grades wherever their tracks are crossed by street car lines.

The Chicago & North Western Railway finds that it would be necessary to rehabilitate a considerable mileage of yard and industrial track, and to proceed with an extensive reconstruction and redistribution of signals along its lines. It estimates that several millions of dollars would be needed for these necessary preliminaries to electrification.

The Illinois Central Railroad has called attention to the fact that its suburban and freight tracks now occupy different portions of the right-of-way, the arrangement being such that the suburban lines cross and recross the lines of other services. A rearrangement of tracks to avoid the repeated grade crossings of the tracks of one service over the tracks of another is, it believes, a necessary preliminary to electrification. Such a change would constitute an improvement of the terminal irrespective of electrification, but in the absence thereof it might be long delayed. While a preliminary to electrification, its cost obviously cannot be included in the cost of electrification. The cost would aggregate several millions of dollars.

The Chicago & Alton Railroad lists a series of items affecting betterments in its permanent way, such as the separation of grades and elevation of tracks, which it regards as imminent but which might, for the time being, be deferred. The total of such items amounts to $820,000, all of which sum would be precipitated by electrification.

The Chicago, Burlington & Quincy Railroad has submitted an itemized list of betterments which might be deferred for many years, but would become at once necessary if electrification were decided upon. The list of these precipitated costs covers items for grade separation, for an extension of four track work where two tracks are now provided, for grade reduction and for changes incident thereto, and for relaying rails in certain yards. The estimated total cost of such work amounts to $2,501,080.

The Michigan Central Railroad, which has only a small amount of trackage within the city of Chicago but which would be required by operating conditions to extend electrified service a considerable distance beyond the city, expresses the belief that the imminence of electrification would require it to elevate tracks for the purpose of separating grades, to an extent which would involve a cost of $3,500,000; the change in operation would also involve the reorganization of yard work and the construction of new classification yards which are not provided for by the estimates of the Committee, but which are estimated to cost $1,500,000. The total precipitated costs for this road will, therefore, amount to $5,000,000.

An officer of the Chicago & Western Indiana Railroad and of the Belt Railway of Chicago notes that these roads are already committed to track elevation under contract ordinances with the city requiring work which will involve the expenditure of approximately $10,000,000, and that in addition to this there would be precipitated an amount of track elevation and grade elimination which might otherwise be long delayed, the estimated cost of which is $8,000,000.

Such precipitated costs are not direct charges against electrification, but they operate to augment the capital requirements at the time of electrification.

213.115 A Generalization Concerning Indeterminate Costs: The preceding sections serve to show the character of the sources from which indeterminate costs will arise. They may be grouped into two divisions, as follows:

1. Those resulting from individual interpretations (based upon an intimate knowledge of present and prospective operating conditions) of the requirements of individual roads.
2. Those which are obviously not a part of the electrification costs but which are precipitated thereby, and which as a consequence enter as a part of the capital requirements incident to electrification.

The effect in both cases is to add to the financial burden which, in the event of electrification, would need to be assumed by the railroads. The Chicago & North Western Railway, which has made estimates paralleling those of the Committee, reports that the total burden which would be imposed upon it by electrification would be more than 30 per cent in excess of the direct costs as set forth by the Committee. The Chicago, Burlington & Quincy Railroad, after a careful study of its problem, estimates that its burden would be more than double the direct costs as set forth by the Committee.

Such statements do not discredit the Committee's estimates. The estimates set forth represent, with as much accuracy as any schedule of estimates can, the direct costs of electrification under prescribed conditions. Any attempt on the part of the Committee to formulate estimates which would do more than this leads at once to uncertain and even to speculative procedures. The Committee cannot concern itself with the amount which a railroad may choose to spend under certain conditions; it can only determine what it must spend to accomplish a specific object. The Committee cannot say what, in the event that electrification is required, a railroad will prefer to have included in its electrified limits; it can only say what must be included, where the object is the elimination of the steam locomotive from the city of Chicago, to constitute a workable arrangement. The Committee cannot determine the nature and extent of a railroad's plans for future betterments, when such betterments are independent of the problem of electrification; it can only recognize the fact that such plans must exist and that work contemplated by them will in many cases be precipitated by a decision to electrify. Many of the problems thus arising are the normal problems of the railroad. Many of them will be settled irrespective of the problems of electrification. The purpose of the Committee is to recognize them as significant factors, the effect of which is to complicate and to extend the problem of electrification.

213.116 Indeterminate Costs as Interpreted by the Railroads Affected: Following the work of the Committee, a number of the Chicago railroads have made a study of the costs which would be imposed upon them, in the event of electrification, in excess of those set forth by the Committee. Eight of these railroads have filed with the Committee the results of their investigations. The reports thus submitted have been analyzed with results which may be set forth as follows:

1. Costs due to an extension of the plan of electrification over that provided by the Committee's estimates	$20,872,500	
2. Precipitated costs, principally for track elevation	29,198,400	
3. Total cost to the eight railroad corporations in excess of that necessary to electrification under the plan of the Committee		$50,070,900
4. The Committee's estimate of the cost of electrification for the eight railroads represented in the preceding statement		$92,599,908
5. The excess costs, including costs due to extensions of the plan and precipitated costs, in per cent of those which are covered by the Committee's estimates		54.07 per cent

The Committee's estimates of the net cost of electrification for all the railroads in the Chicago terminals total $178,127,230. If it be assumed that the costs to all railroads, due to extensions of plans beyond those provided by the Committee and to betterments which are precipitated by electrification, will bear the same relation to the Committee's estimates as those of the eight railroads which have analyzed the problem, the total added and precipitated costs to be provided for by all roads will amount to $96,313,400.

Upon this basis, the total capital requirement imposed by electrification will be:

That incident to the development of a minimum plan as estimated by the Committee	$178,127,230	
That required to cover precipitated costs and costs due to extensions of the plan	96,313,400	
Total		$274,440,630

THE ESTIMATED COST OF ELECTRIFICATION BY SYSTEMS

213.117 General Considerations: In the preceding sections of this chapter the costs of all features entering into the electrification of the Chicago railroad terminals, by the 2,400-volt direct current and the 11,000-volt alternating current overhead contact systems of traction, have been set forth for all roads. It has been explained (section 212.01) that the cost of electrification by the 600-volt direct current third rail system has been determined in detail for one road only, the Chicago & North Western Railway. The total cost thus obtained has been extended to make up the total cost of electrification by the third rail system for all roads. This extension has involved the determination of the cost of electrification for this road, independent of all others, by each of the three systems under consideration.

It is assumed, for purposes of extension, that the ratios found to exist between the costs of electrification for this road by the third rail system, and the costs by each of the other two systems, may be applied to the estimated costs of electrification of the entire terminal by the 2,400-volt and 11,000-volt systems, to obtain the cost of electrification of the entire terminal by the 600-volt direct current third rail system. This process has saved time and labor as compared with that which would have been required had the costs of electrification, by the 600-volt third rail system, to all roads been determined in detail as for the other two systems. The results are believed to be sufficiently accurate for the present purpose.

213.118 Influences Governing the Selection of the Chicago & North Western Railway as a Basis for Determining the Cost of Third Rail Electrification: The Chicago & North Western Railway was selected as the road for which the cost of the third rail system was to be developed, because it includes in its activities all the services operated on the terminals and also because its operations are but little complicated by those of other roads. Data showing the character and magnitude of the services and the energy required have been presented in chapter 211. The total mileage to be electrified, for which the estimates have been developed, is shown in the following:

	MILES
Main tracks	263.46
Other tracks	258.71
Adjacent industrial tracks privately owned	9.83
Total	532.00

This mileage does not include the trackage of the St. Charles Air Line owned jointly by the Chicago & North Western Railway and other roads. Operation over the St. Charles Air Line, and over the tracks of the Chicago Junction Railway from the Wood Street Yard to the Union Stock Yards, is not included.

213.119 Power Station: It has been assumed that a single power station located near the center of load will be provided. The exact location is immaterial for the purpose of this estimate, but it has been assumed as being on the North Branch of the Chicago River between North Avenue and Fullerton Avenue. The same assumptions have been made for this station regarding character of site and subsoil, and general arrangement of building and equipment, as were made for the station designed to serve all roads for the 2,400-volt direct current and the 11,000-volt alternating current systems of traction (section 213.004).

The loads upon this station are so nearly the same for the three systems that the same number and capacity of turbine generating sets have been specified for all systems. The estimates are based upon the use of three steam turbine generating sets, each of 15,000 kilowatts continuous capacity. These differ only in capacity from those described (section 213.004). This allows one spare unit, since two generators are sufficient to carry the maximum load. As in the case of the power station for the joint operation of all roads, the number of boilers has been made to conform to the difference in load resulting from the choice of system. The number is the same for the 600-volt and 2,400-volt direct current systems, but is less for the 11,000-volt alternating current system.

The station characteristics and loads for each of the three systems considered are shown by table CCCXLIX.

From the lay-out of the plant described and from facts otherwise available, an estimate of the cost of the plant required for each of the three systems, excluding all allowances for contingencies and for engineering, has been prepared with results which are presented in table CCCL.

The installation costs shown by these items, based upon an installed capacity of 45,000 kilowatts, amount to $49.39 per kilowatt for both the 600-volt and the 2,400-volt direct current systems, and to $49.43 for the 11,000-volt alternating current system. If, to these substantially equal unit costs 10 per cent is added for contingencies and 10 per cent for engineering, the installation cost will be approximately $60.00 per kilowatt in each case. Such additions are hereinafter provided for. It should be noted that, in arriving at the unit cost, the same rating is assumed for all plants, notwithstanding the fact that there is less boiler capacity in the plant designed to serve the alternating current system than is provided for in the design which has served as a basis for the cost of both of the direct current systems.

The total cost shown by table CCCL represents the costs of labor and material on the basis of the requirements of 1912. These have been extended in a manner normal to these estimates (section 212.09) to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the

TABLE CCCXLIX. POWER STATION CHARACTERISTICS AND LOADS
(Chicago & North Western Railway)
(Basis of 1912)

Details	600-Volt D. C.	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Peak load, one hour, kw	29,150	29,200	25,935
Estimated power factor of load, per cent	95	95	70
Load factor, per cent	51.9	50.9	52.7
Output per day, kw-hr	363,300	356,700	328,030
Output per year, kw-hr	132,968,000	130,552,000	120,059,000
Number of generating units provided	3	3	3
One hour continuous capacity of units, kw	15,000	15,000	15,000
Maximum overload capacity, kw	20,000	20,000	20,000
Rating of two units in service on maximum load, kw	30,000	30,000	30,000
Loading of generators during maximum hour, per cent	97.2	97.3	86.4
Total installed capacity, kw	45,000	45,000	45,000
Installed capacity of step-up transformers, kv-a	30,000	30,000	30,000
Maximum capacity of transformers for five minutes, per cent of full load	200	200	200

TABLE CCCL. ESTIMATED COST OF POWER STATION, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING
(Chicago & North Western Railway)
(Basis of 1912)

Item	600-Volt D. C.	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Real estate, foundations, intake and discharge tunnels and buildings complete	$889,920	$889,920	$889,920
Boilers, stokers, pumps, piping, flues, chimneys, coal and ash handling plant and other boiler plant accessories	535,820	535,820	500,140
Turbine units, condensers, switchboards, exciters, step-up transformers, crane and other turbine accessories	796,950	796,950	834,450
Totals	$2,222,690	$2,222,690	$2,224,510

same as those used for the power station for the entire terminal (section 213.006). The estimated total cost of the power station for the Chicago & North Western Railway, on the basis of the requirements of 1922, including the cost of real estate, building and equipment for each of the three systems, is as follows:

600-volt direct current	$3,863,402
2,400-volt direct current	3,863,402
11,000-volt alternating current	3,866,565

213.120 Transmission System: The same general considerations, in so far as they apply, have governed the estimates of cost of the transmission system for the single road as were followed for all the roads (section 213.007). Three-phase, 33,000-volt transmission circuits are to be used for the 600-volt system. In all cases the transmission wire is to be No. 1 A. W. G., a smaller size not being considered satisfactory mechanically and a larger size not being required electrically. The resulting transmission efficiencies are:

	PER CENT
600-volt direct current system	99.5
2,400-volt direct current system	99.1
11,000-volt alternating current system	98.7

The routes and make-up of the transmission circuits are shown by figs. 681 to 683, inclusive, for the 600-volt and 2,400-volt direct current and the 11,000-volt alternating current systems, respectively.

The length and weight of No. 1 copper wire required for transmission lines for each system are given in table CCCLI.

TABLE CCCLI. WIRE REQUIRED FOR TRANSMISSION SYSTEM.
(Chicago & North Western Railway)
(Basis of 1912)

System	Miles	Pounds
1	2	3
600-volt direct current	444.0	593,000
2,400-volt direct current	295.5	395,000
11,000-volt alternating current	273.0	366,000

The load imposed by the transmission circuits of the 2,400-volt and 11,000-volt systems on the structures of the contact system does not exceed that which served as a basis for the design of these structures, and no additional steel or concrete will, therefore, be required. For the 600-volt system, steel poles or towers have been designed to carry the transmission lines. These are to be spaced at intervals of 300 feet on tangent track and will support the lowest transmission wire 30 feet above the ground at the pole, or at a minimum height of 25 feet at the center of span under conditions of maximum sag. Duplicate circuits are to be provided, and where these are run on the same right-of-way they are to be placed on the same poles.

Two river crossings at drawbridges will require special towers for supporting the conductors for the 2,400-volt and 11,000-volt systems at

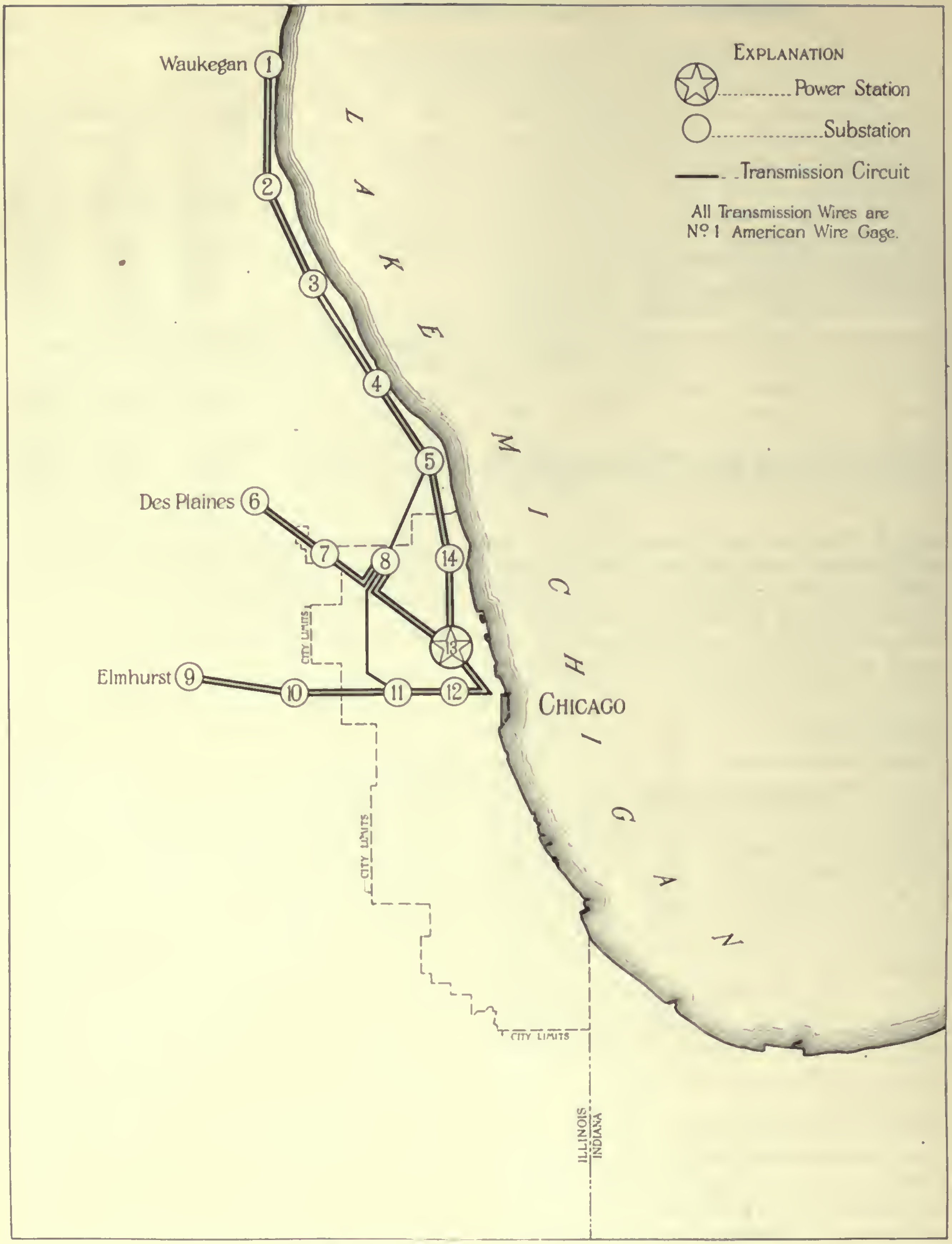

FIG. 681. TRANSMISSION CIRCUITS FOR THE 600-VOLT D. C. SYSTEM
CHICAGO & NORTH WESTERN RAILWAY

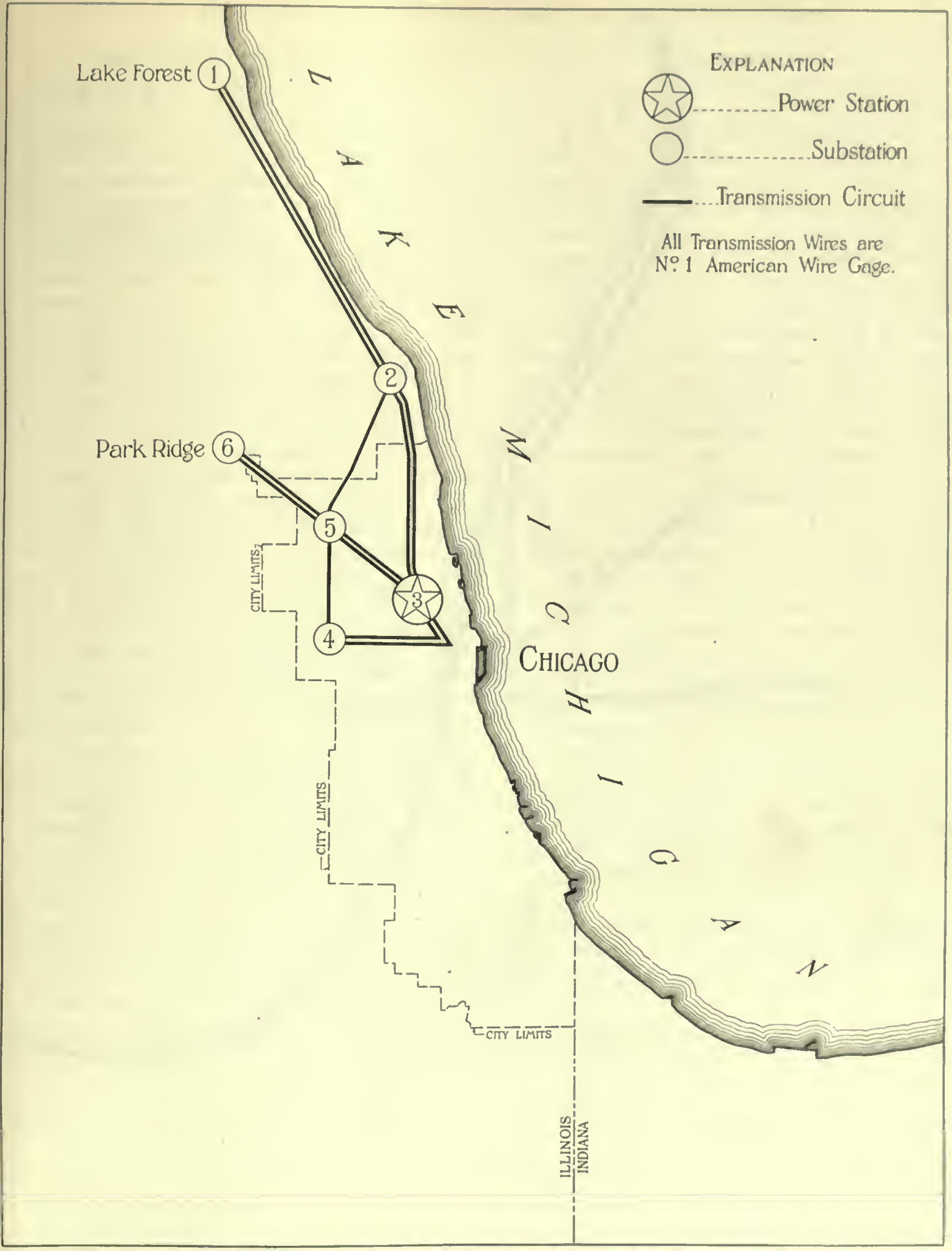

FIG. 682. TRANSMISSION CIRCUITS FOR THE 2,400-VOLT D. C. SYSTEM CHICAGO & NORTH WESTERN RAILWAY

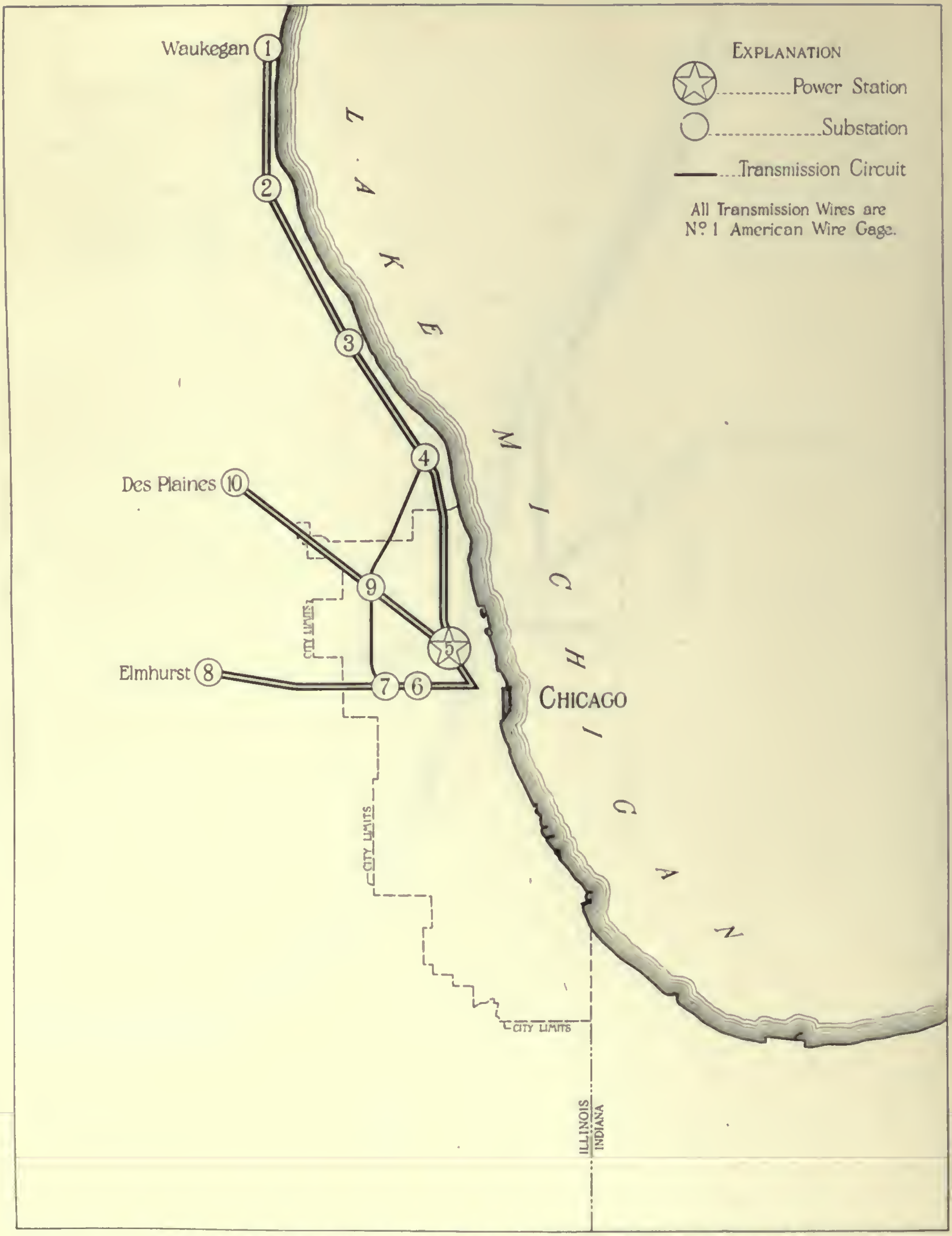

FIG. 683. TRANSMISSION CIRCUITS FOR THE 11,000-VOLT A. C. SYSTEM CHICAGO & NORTH WESTERN RAILWAY

a minimum height of 120 feet above the water. At the crossing of the North Branch of the Chicago River near Fullerton Avenue the towers will be required to support transmission circuits, ground wires and the wires to make the trolley and return circuits continuous. At the crossing near Kinzie Street the towers will support only the ground wires and the trolley and return circuits. In the cost of these crossings has also been included the cost of the additional steel and concrete required at both ends of each bridge draw to dead-end the contact wires. For the 600-volt system towers for the transmission lines will be necessary only at the crossing near Fullerton Avenue. These towers will support, in addition to the transmission and ground wires, six 1,000,000 circular mil cables to preserve the continuity of the third rail and return circuits when the draw is opened, and the cost of these cables is included in the cost of river crossings as a part of the cost of the transmission system. At the drawbridge near Kinzie Street no towers will be required for the 600-volt system, since there will be no transmission lines crossing at this point and the third rail and return circuits will cross as submarine cables. Their cost is included with the cost of third rail contact and return circuit.

For the 600-volt system the estimates include the cost of a ground wire to be carried on the transmission poles for the entire length of the transmission lines. For the 2,400-volt and 11,000-volt systems, both employing overhead contact, the estimates provide for the cost of two ground wires, one on each side of the right-of-way on the extension to the posts or poles of the structures supporting the contact system, regardless of whether or not there may be transmission lines on the structures.

By the use of substantially the same unit costs as are set forth in section 213.011, an estimate of the cost of the transmission system required for each of the three systems of traction has been prepared and is presented in table CCCLII.

The total cost shown by table CCCLII represents the cost of labor and materials on the basis of the requirements of 1912. This has been extended in a manner normal to these estimates (section 212.09), to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those used for the transmission system for the entire terminal (section 213.013). The estimated total cost of the transmission system for the Chicago & North Western Railway, on the basis of the requirements of 1922, is as follows:

600-volt direct current	$974,863
2,400-volt direct current	279,743
11,000-volt alternating current	267,475

213.121 Substations: The general conditions which govern the location of substations for the electrification of all roads by the 2,400-volt and 11,000-volt systems, as set forth in section 213.014, have also controlled in determining the location of substations for these systems for the Chicago & North Western Railway independently. For the 600-volt third rail system a spacing of substations of from three to six miles, depending upon the load conditions, has been used. With the locations assumed, the extreme momentary drop in voltage under maximum starting conditions will not exceed 300 volts in the outlying districts and will be much less within the city limits.

The proposed locations of substations for the three systems of electrification for the Chicago & North Western Railway are shown by figs. 684 to 686, inclusive.

TABLE CCCLII. ESTIMATED COST OF TRANSMISSION SYSTEM, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING

(Chicago & North Western Railway)

(Basis of 1912)

Item	600-Volt D. C.	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Copper wire	$110,500	$73,600	$68,200
Insulators	22,880	15,230	14,060
Erection of wire and insulators	36,190	22,200	20,500
Ground cables, material and erection	10,850	24,700	24,700
Steel and concrete, pole line	327,000	0	0
Towers and foundations at river crossing	5,700	10,600	10,000
Towers and foundations where bridges cross over tracks	1,000	1,200	3,600
Totals	$514,120	$147,530	$141,060

FIG. 684. LOCATIONS OF POWER STATION AND SUBSTATIONS FOR THE 600-VOLT D. C. SYSTEM. CHICAGO & NORTH WESTERN RAILWAY

FIG. 685. LOCATIONS OF POWER STATION AND SUBSTATIONS FOR THE 2,400-VOLT D. C. SYSTEM. CHICAGO & NORTH WESTERN RAILWAY

FIG. 686. LOCATIONS OF POWER STATION AND SUBSTATIONS FOR THE 11,000-VOLT A. C. SYSTEM. CHICAGO & NORTH WESTERN RAILWAY

The characteristics of substations and substation equipment, upon which the estimates of cost for the single road have been based, are generally the same as those for the 2,400-volt direct current and the 11,000-volt alternating current systems, as described in section 213.015, the capacity of the apparatus for the single road being generally smaller than that required by all roads. For the 600-volt system the characteristics of the substation buildings and equipment are similar to those required for the 2,400-volt system, the only material difference being in the use of single rotary units instead of double units. For the 600-volt system 14 substations having individual capacities varying from 2,000 to 6,000 kilowatts will be required. Of these substations, ten are to be equipped to act as tie-stations for the transmission lines. For the 2,400-volt system six substations are to be provided, with individual capacities varying from 2,000 to 10,000 kilowatts. Three of these will act as transmission line tie-stations. For the 11,000-volt system, ten substations are to be provided, with individual capacities varying from 3,000 to 12,000 kilowatts. Six of these will serve as tie-stations for the transmission lines. The loads, capacities and other characteristics of substations are shown for each of the three systems in tables CCCLIII to CCCLV, inclusive.

TABLE CCCLIII. CHARACTERISTICS OF SUBSTATIONS FOR THE 600-VOLT D. C. SYSTEM

(Chicago & North Western Railway)

Substation No.*	Input to Substation for Average Day, Kilowatt-Hours			Load Factor, Per Cent	Units		Total Rated Capacity, Kilowatts
	Average Hour	Maximum Hour	Total		No.	Capacity, Kilowatts	
1	2	3	4	5	6	7	8
1	278	571	6,672	48.7	2	1,000	2,000
2	422	864	10,128	48.8	2	1,000	2,000
3	486	1,239	11,664	39.2	2	1,000	2,000
4	514	1,647	12,336	31.2	2	1,000	2,000
5	650	2,182	15,600	29.8	3	1,000	3,000
6	336	875	8,064	38.4	2	1,000	2,000
7	535	1,357	12,840	39.4	2	1,000	2,000
8	581	834	13,944	69.6	2	1,000	2,000
9	293	751	7,032	39.0	2	1,000	2,000
10	659	1,206	15,816	54.6	2	1,000	2,000
11	4,280	5,840	102,720	73.2	3	2,000	6,000
12	2,050	2,640	49,200	77.7	3	1,000	3,000
13†	2,830	6,880	67,920	41.1	3	2,000	6,000
14	738	2,795	17,712	26.4	3	1,000	3,000
Totals	14,652	28,231	351,648	51.9	33	....	39,000

* See fig. 684. † In power station.

TABLE CCCLIV. CHARACTERISTICS OF SUBSTATIONS FOR THE 2,400-VOLT D. C. SYSTEM

(Chicago & North Western Railway)

Substation No.*	Input to Substation for Average Day, Kilowatt-Hours			Load Factor, Per Cent	Units		Total Rated Capacity, Kilowatts
	Average Hour	Maximum Hour	Total		No.	Capacity, Kilowatts	
1	2	3	4	5	6	7	8
1	1,285	2,785	30,840	46.1	4	1,000	4,000
2	1,370	4,700	32,880	29.1	4	1,500	6,000
3†	3,420	8,080	82,080	42.3	4	2,500	10,000
4	6,130	8,640	147,120	70.9	4	2,500	10,000
5	1,565	2,900	37,560	54.0	4	1,000	4,000
6	600	1,560	14,400	39.6	2	1,000	2,000
Totals	14,370	28,232	344,880	50.9	22	....	36,000

* See fig. 685. † In power station.

TABLE CCCLV. CHARACTERISTICS OF SUBSTATIONS FOR THE 11,000-VOLT A. C. SYSTEM

(Chicago & North Western Railway)

Substation No.*	Input to Substation for Average Day, Kilowatt-Hours			Load Factor, Per Cent	Units		Total Rated Capacity, Kilovolt-Amperes
	Average Hour	Maximum Hour	Total		No	Capacity, Kilovolt-Amperes	
1	2	3	4	5	6	7	8
1	240	491	5,760	48.9	2	1,500	3,000
2	564	1,238	13,536	45.6	2	1,500	3,000
3	616	1,877	14,784	32.9	2	2,000	4,000
4	936	3,230	22,464	29.0	2	3,000	6,000
5†	2,800	6,720	67,200	41.7	2	6,000	12,000
6	2,160	3,010	51,840	71.8	2	3,000	6,000
7	3,090	4,230	74,160	72.9	2	4,000	8,000
8	662	1,335	15,888	49.7	2	1,500	3,000
9	1,620	3,140	38,880	51.5	2	3,000	6,000
10	393	1,015	9,432	38.7	2	1,500	3,000
Totals	13,081	24,822	313,944	52.7	20	....	54,000

* See fig. 686. † In power station.

TABLE CCCLVI. ESTIMATED COSTS OF SUBSTATIONS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING, 600-VOLT D. C. SYSTEM

(Chicago & North Western Railway)

(Basis of 1912)

Substation No.	Total Capacity of Installation, Kilowatts	Cost
1	2	3
1	2,000	$ 65,800
2	2,000	65,800
3	2,000	65,800
4	2,000	65,800
5	3,000	97,400
6	2,000	65,800
7	2,000	65,800
8	2,000	68,080
9	2,000	67,780
10	2,000	65,800
11	6,000	127,630
12	3,000	96,900
13*	6,000	112,620
14	3,000	95,910
Totals..............	39,000	$1,126,920

* In power station.

Estimates of the costs of the substations required for each of the three systems for the Chicago & North Western Railway have been prepared in the manner described in section 213.016. These estimated costs are presented in tables CCCLVI to CCCLVIII, inclusive.

The total costs presented in the tables referred to represent the costs of labor and material on the basis of the requirements of 1912. These have been extended in a manner normal to these estimates (section 212.09), to cover growth.

TABLE CCCLVII. ESTIMATED COSTS OF SUBSTATIONS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING, 2,400-VOLT D. C. SYSTEM
(Chicago & North Western Railway)
(Basis of 1912)

Substation No.	Total Capacity of Installation, Kilowatts	Cost
1	2	3
1	4,000	$169,930
2	6,000	199,600
3*	10,000	231,520
4	10,000	255,790
5	4,000	178,060
6	2,000	99,290
Totals.	36,000	$1,134,190

* In power station.

TABLE CCCLVIII. ESTIMATED COSTS OF SUBSTATIONS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING, 11,000-VOLT A. C. SYSTEM
(Chicago & North Western Railway)
(Basis of 1912)

Substation No.	Total Capacity of Installation, Kilowatts	Cost
1	2	3
1	3,000	$24,910
2	3,000	26,700
3	4,000	27,860
4	6,000	34,400
5*	12,000	38,440
6	6,000	31,600
7	8,000	38,560
8	3,000	30,270
9	6,000	31,930
10	3,000	24,910
Totals	54,000	$309,040

* In power station.

contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those used for the substations for the entire terminal (section 213.017). The estimated total cost of the substations for the Chicago & North Western Railway, on the basis of the requirements of 1922, is as follows:

600-volt direct current	$1,958,773
2,400-volt direct current	1,971,409
11,000-volt alternating current	538,205

213.122 Switching Stations: Switching stations similar to those described in section 213.019 have served as a basis for estimates of cost for the 2,400-volt and 11,000-volt systems for the Chicago & North Western Railway. The switching stations for the 600-volt third rail system have been assumed to consist of groups of distant-controlled carbon break circuit breakers housed in small inexpensive buildings. For all the systems it is assumed that the circuit breakers in the switching stations will be controlled from a neighboring interlocking tower, station or other building in which an employe will always be on duty.

The number, characteristics and estimated costs of the switching stations required for each of the three systems are presented in tables CCCLIX to CCCLXI, inclusive.

TABLE CCCLIX. ESTIMATED COSTS OF SWITCHING STATIONS EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING, 600-VOLT D. C. SYSTEM
(Chicago & North Western Railway)
(Basis of 1912)

Number of Stations	Number of Feeders per Station	Cost per Station, Complete	Total Cost
1	2	3	4
6	4	$ 3,150	$18,900
2	5	3,900	7,800
5	6	4,500	22,500
1	9	6,450	6,450
1	10	7,050	7,050
1	12	8,400	8,400
1	16	10,950	10,950
17		. .	$82,050

TABLE CCCLX. ESTIMATED COSTS OF SWITCHING STATIONS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING, 2,400-VOLT D. C. SYSTEM
(Chicago & North Western Railway)
(Basis of 1912)

Number of Stations	Number of Feeders per Station	Cost per Station, Complete	Total Cost
1	2	3	4
11	4	$ 3,350	$36,850
2	5	4,150	8,300
7	6	4,800	33,600
1	8	6,250	6,250
1	10	7,550	7,550
1	12	9,000	9,000
1	16	11,750	11,750
24		. . . .	$113,300

TABLE CCCLXI. ESTIMATED COSTS OF SWITCHING STATIONS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING, 11,000-VOLT A. C. SYSTEM
(Chicago & North Western Railway)
(Basis of 1912)

Number of Stations	Number of Feeders per Station	Cost per Station, Complete	Total Cost
1	2	3	4
10	4	$1,400	$14,000
2	5	1,750	3,500
7	6	2,100	14,700
1	12	4,200	4,200
1	13	4,550	4,550
1	16	5,600	5,600
22			$46,550

The total costs presented in the preceding tables represent the costs of labor and materials on the basis of the requirements of 1912. These have been extended in a manner normal to these estimates (section 212.09), to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those used for the switching stations for the entire terminal (section 213.021). The estimated total costs of the switching stations for the Chicago & North Western Railway, on the basis of the requirements of 1922, are as follows:

600-volt direct current	$142,616
2,400-volt direct current	196,934
11,000-volt alternating current	80,912

213.123 Contact System: The types of contact, upon which estimates are based, include the third rail for the 600-volt direct current system and the overhead catenary construction for the 2,400-volt direct current and the 11,000-volt alternating current systems.

Two types of third rail are available, the top contact type and the under contact type. These have been described in chapter 207. For the purpose of these estimates, the top contact type has been used.

As a preliminary to the preparation of estimates of the cost of the third rail and its appurtenances, the location and arrangement of all third rail conductors were carefully laid out on the track plans for both main and yard tracks. For main tracks and ladder tracks in yards, the third rail conductor is to be of special composition low resistance steel, weighing 150 pounds per yard. For other yard and industrial track the conductor rail is to be of steel of standard composition and section, weighing 25 pounds per yard. The 150-pound section is to be bonded at joints with four 450,000 circular mils copper bonds and the 25-pound section is to be bonded with two No. 0000 A. W. G. bonds. The third rail is to be made as nearly continuous as local conditions will permit. Gaps will be necessary at certain types of switches and other complicated track work and at highway, foot-path and railroad crossings. Some of these gaps will not be more than a few feet in length and trains can be operated over them without difficulty, but others will be of such length or so located that a supplementary means of providing continuous contact will be necessary. At such places it is assumed that an overhead contact rail will be used, the tracks rearranged or the length of the gap reduced in some other manner. Where a gap in the third rail is necessary, the continuity of the electric circuit is maintained by underground jumpers. These are to be of insulated cable installed in iron pipe and provided with suitable potheads and terminals for connection to the ends of the third rail. Those for the 150-pound third rail will be of 2,000,000 circular mils and those for the 25-pound rail will be of 750,000 circular mils. The overhead contact rail for use at places where the third rail is impracticable is to be of steel T-bar, weighing five pounds per foot, placed in an inverted position. Where joints occur they are to be bonded with No. 0000 A. W. G. copper bonds. This contact rail is to be supported from a steel messenger cable by hangers of such length that the contact will normally be 24 feet, 2 inches, above the top of the track rails. The messenger cable or catenary is to be supported by steel poles or bridges similar to those for the overhead contact systems (section 213.025). These supporting structures will be spaced at intervals of not more than 150 feet. In locations where overhead contact rail is required for tracks in streets, the supports are to be located on the curb line. When overhead contact rail is required in locations where there are overhead obstructions, such as under bridges or other structures, it is to be supported from the existing obstruction and the normal height is to be reduced as conditions require, but in no case is it to be less than 16 feet. Over slip switches a grid of three T-irons bolted together and supported by pipe spacers is to be used instead of a single contact. Connection between the overhead rail and the third rail is to be made by means of insulated cable. Gaps requiring the use of overhead contact rail occur at the following locations:

1. Passenger terminal stations.
2. Main tracks at streets or railroad crossings near stations and near switches to industrial, yard or side tracks.
3. Yard ladder tracks and at throats of yards.
4. Industrial and team tracks at street crossings.
5. Double slip switches.

The use of the third rail will require all tracks to be adequately protected by fences. Although much of the trackage of the Chicago & North Western Railway is at present fenced, additional right-of-way fence, inter-track fence and cattle-guards with wing fences will be required. As a basis for the estimates, it has been assumed that the right-of-way fence will consist of woven wire, 4 feet, 6 inches, high, with stays 6 inches apart, supported by cedar posts, with 6-inch tops, spaced at intervals of 8 feet. This type of fence is now in general use on the lines of the Chicago & North Western Railway in and near Chicago. A wooden picket fence 4 feet, 6 inches, high is to be provided for inter-track fence. The wing fence is to consist of wooden rails and is to be 4 feet, 4 inches, high. Cattle-guards are to be of vitrified tile.

A submarine cable is to be provided at the river crossing near Kinzie Street. Two 1,000,000 circular mils armored insulated cables are to be provided for preserving continuity of third rail circuit.

The following unit costs have been used in estimating the cost of the third rail contact system:

150-pound third rail, installed with protection and bonding, per mile	$8,500.00
25-pound third rail, installed with protection and bonding, per mile	4,000.00
13-foot jumpers, 2,000,000 circular mils each	95.00
13-foot jumpers, 750,000 circular mils each	65.00
Additional length of jumper, 2,000,000 circular mils per foot	3.00
Additional length of jumper, 750,000 circular mils per foot	1.70
Right-of-way fence, per mile	576.00
Inter-track fence, per foot	0.60
Wing fence, per foot	0.35
Cattle-guards in place, per set	20.00

The estimated costs of the contact construction required for the 600-volt direct current third rail system, excluding all allowances for contingencies and for engineering, on the basis of 1912, are shown by table CCCLXII.

TABLE CCCLXII. ESTIMATED COSTS OF CONTACT CONSTRUCTION, 600-VOLT D. C. THIRD RAIL SYSTEM

(Chicago & North Western Railway)

(Basis of 1912)

Item	Total Cost
Third rail	$3,428,290
Overhead contact rail	286,250
Fences and cattle-guards	30,040
Submarine crossing	3,350
Total	$3,747,930

The estimates presented in table CCCLXII do not include the cost of changes to structures to permit the installation of the third rail conductors. The character of these changes and their cost are given in section 213.130.

The type of construction required for the overhead contact system for the 2,400-volt direct current and the 11,000-volt alternating current systems has been described (sections 213.022 to 213.025, inclusive, and in sections 213.028 and 213.029). The unit costs there given have also been used in estimating the cost of the contact required on the Chicago & North Western Railway for both these systems. The costs determined by this process, excluding all allowances for contingencies and for engineering, on the basis of 1912, are as follows:

2,400-volt direct current	$2,800,231
11,000-volt alternating current	2,273,727

The estimated cost presented for the overhead contact systems does not include the cost of changes to wire lines and structures nor the cost of bridge warnings. These are set forth in sections 213.124 and 213.131.

The degree to which the several classes of track are responsible for the cost of the contact system and its accessories is shown by table CCCLXIII.

TABLE CCCLXIII. ESTIMATED COSTS OF CONTACT SYSTEM, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING

(Chicago & North Western Railway)

(Basis of 1912)

System	Main Tracks	All Other Tracks	Adjacent Industrial Tracks Privately Owned	Total for All Tracks
1	2	3	4	5
600-volt direct current..	$2,355,220	$1,344,075	$48,635	$3,747,930
2,400-volt direct current	1,783,780	974,480	41,962	2,800,231
11,000-volt alt'g current	1,355,679	878,494	39,554	2,273,727

The costs shown by table CCCLXIII represent the cost of labor and materials for all systems on the basis of the requirements of 1912. These have been extended in a manner normal to these estimates (section 212.09), to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those used for the contact system for the entire terminal (section 213.032). The estimated total cost of the contact system for the Chicago & North Western Railway, on the basis of the requirements of 1922, is as follows:

600-volt direct current	$7,106,749
2,400-volt direct current	5,309,742
11,000-volt alternating current	4,311,396

An examination of the extent to which each of the two types of contact systems, for which estimates have been prepared, is applicable to the existing conditions, is of interest. In a number of cases where tracks are located in streets, buildings or repair yards, a careful study reveals no means by which the third rail contact, even in connection with the overhead contact rail, can be satisfactorily applied. In some locations, also, conditions will not permit the installation of any type of contact construction suitable for the 2,400-volt or the 11,000-volt systems. As a result of these limitations there are 11.65 miles of track, comprising 9.15 miles of dock and shop yard tracks and 2.5 miles of industry and repair tracks, which cannot be electrically equipped and operated by the 600-volt third rail system, and 3.5 miles of track, of which 1.71 miles are repair and shop yard tracks and 1.79 miles are industrial tracks, which cannot be equipped for operation with either the 2,400-volt or the 11,000-volt overhead contact systems. Trackage of this kind would, in the event of the complete elimination of the steam locomotive, necessarily be operated by some one of the specialized forms of locomotives discussed in chapter 204.

213.124 Bridge Warnings: In section 213.023 it has been shown that, for both systems employing overhead contact, special bridge warnings will be required to protect trainmen on tops of cars. Although some overhead contact will be used for the third rail system, bridge warnings will not be needed for this system. The overhead third rail, where used, will be maintained at a safe height except where existing overhead obstructions prevent, in which cases the warnings now used for the obstruction will suffice. Electrification of the Chicago & North Western Railway, with either the 2,400-volt direct current system or the 11,000-volt alternating current system will require special bridge warnings over 118 main tracks and over 149 other tracks. Applying the unit costs used for the entire terminal (section 213.034), namely, $500.00 for each main track warning and $50.00 for each yard or industrial track warning, the costs of bridge warnings, excluding all allowances for contingencies and for engineering, on the basis of 1912, is estimated as shown in table CCCLXIV.

TABLE CCCLXIV. ESTIMATED COSTS OF BRIDGE WARNINGS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING
(Chicago & North Western Railway)
(Basis of 1912)

System	Main Tracks	All Other Tracks	Total
1	2	3	4
600-volt direct current	$ 0	$ 0	$ 0
2,400-volt direct current	59,000	7,450	66,450
11,000-volt alternating current	59,000	7,450	66.450

The costs shown by table CCCLXIV represent, for the three systems, the costs of labor and materials on the basis of the requirements of 1912. These have been extended in a manner normal to these estimates (section 212.09), to cover growth. contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those applied to the estimates of costs of bridge warnings for the entire terminal (section 213.036). The estimated total cost of bridge warnings for the Chicago & North Western Railway, on the basis of requirements of 1922, is as follows:

600-volt direct current	$ 0
2,400-volt direct current	108,554
11,000-volt alternating current	108,554

213.125 Return Circuit: The estimates of cost of track bonding for the Chicago & North Western Railway for the 2,400-volt direct current and the 11,000-volt alternating current systems are based upon the unit costs employed in determining the cost of bonding for all railroads (section 213.041). For the 600-volt direct current system, the character of bonding selected as a basis of estimates is the same as that used as a basis for the estimates of bonding for the 2,400-volt direct current system. The unit costs set forth in section 213.041 for the 2,400-volt system have been used in preparing estimates for the 600-volt system, with an addition of $15.00 per mile of main track to the cost of the substation connections, this addition being due to the greater number of substations required for the 600-volt system. The cost of new splice bars for all tracks to be bonded is the same for the three systems. At the Chicago River crossing near Kinzie Street a 1,000,000 circular mils submarine cable is to be provided for the 600-volt direct current system, to preserve the continuity of the return circuit. The cost of this cable is estimated as $1,650, and this amount is included in the total cost of bonding main tracks.

The estimated costs of labor and materials for track bonding, and other items which go to make up the return circuit for each of the three systems and for the several classes of track, based upon the requirements of 1912, excluding all allowances for contingencies and for engineering, are given in table CCCLXV.

TABLE CCCLXV. ESTIMATED COSTS OF RETURN CIRCUIT, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING
(Chicago & North Western Railway)
(Basis of 1912)

System	Main Tracks	Other Tracks	Adjacent Industrial Tracks Privately Owned	Total
1	2	3	4	5
600-volt direct current	$356,075	$169,103	$6.103	$531,281
2,400-volt direct current	350,472	174.604	6,103	531,179
11,000-volt alternating current	253,896	129,286	4.628	387.810

The costs shown by table CCCLXV represent the costs of labor and materials on the basis of requirements of 1912. These have been extended in a manner normal to these estimates (section 212.09), to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those used for the return circuit for the entire terminal (section 213.043). The estimated total cost of the return circuit for the Chicago & North Western Railway, based upon the requirements of 1922, is as follows:

600-volt direct current	$1,007,404
2,400-volt direct current	1,007,211
11,000-volt alternating current	735,358

213.126 Prevention of Inductive Effects and Electrolysis: The methods to be employed for overcoming inductive effects with the 11,000-volt alternating current system have been outlined in section 213.044. The substations are to be so located as to provide suitable feeding points and the bonding is to be ample to secure a return circuit of low resistance. Booster transformers are to be provided in the railroad circuits at intervals of about 1.5 miles. The booster transformers will be the only devices provided solely for the prevention of inductive interferences, and therefore their cost constitutes the cost of preventing inductive effects.

Similarly, with the 600-volt and the 2,400-volt direct current systems, liberal bonding and proper location of substations will so reduce the difference of potential in the return circuit that serious damage from electrolysis will not occur. As these measures are beneficial in other respects, no attempt has been made to determine the proportion of their cost which is applicable to the prevention of electrolysis.

The costs of booster transformers, excluding all allowances for contingencies and for engineering, have been determined for the 11,000-volt alternating current system, upon the basis of the requirements of 1912, as set forth in table CCCLXVI.

TABLE CCCLXVI. ESTIMATED COSTS OF BOOSTER TRANSFORMER INSTALLATIONS FOR THE PREVENTION OF INDUCTIVE EFFECTS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING,
11,000- VOLT A. C. SYSTEM
(Chicago & North Western Railway)
(Basis of 1912)

Number of Installations	No. of Tracks at Each Installation	Cost per Installation	Total Cost
1	2	3	4
38	2	$1,000	$38,000
13	3	1,325	17,225
6	4	2,000	12,000
6	6	2,650	15,900
63	.	....	$83,125

The costs shown by table CCCLXVI represent the costs of labor and materials on the basis of the requirements of 1912. These have been extended in a manner normal to these estimates (section 212.09) to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those applied to the estimates of the cost of prevention of inductive effects for the entire terminal (section 213.047). The estimated total cost of preventing inductive effects on the Chicago & North Western Railway, on the basis of the requirements of 1922, is as follows:

600-volt direct current	0
2,400-volt direct current	0
11,000-volt alternating current	$157,620

213.127 Telephone System: The cost of the telephone system required for the Chicago & North Western Railway is the same for the three systems of electrification. The cost of the telephone patrol line is based upon an estimated unit cost of $300 per mile of route. The route mileage of the Chicago & North Western Railway included in the plan of electrification is 91.7. It is assumed that the telephone lines and equipment required for inter-communication between power station, substations and other new facilities to be provided in the event of electrification, will be furnished by the local telephone company upon a rental basis, and that their cost will not be a capital charge. The rental charge will affect the operating expense, as has been previously discussed in section 213.047.

The estimated costs of labor and materials required for the telephone patrol lines for each system, based upon the conditions in 1912, are as follows:

600-volt direct current	$27,510
2,400-volt direct current	27,510
11,000-volt alternating current	27,510

This cost represents the cost of labor and materials on the basis of the requirements of 1912. These have been extended in a manner normal to these estimates (section 212.09), to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those applied to the estimates of the cost of telephone patrol line for the entire terminal (section 213.052). The estimated total cost of the telephone patrol line for the Chicago & North Western Railway, upon the basis of the requirements of 1922, is as follows:

600-volt direct current	$44,138
2,400-volt direct current	44,138
11,000-volt alternating current	44,138

213.128 Electric Locomotives, Multiple-Unit Equipment, Work and Inspection Equipment: The number of electric locomotives required for each class of service and the number of multiple-unit cars required for suburban service are the same for all of the systems of electrification under consideration. The types of locomotive and car equipment required have been described in sections 213.053 to 213.059, inclusive. The work and inspection equipment required for the 2,400-volt direct current system and for the 11,000-volt alternating current system has also been described in that chapter. The inspection cars required for the 600-volt direct current system will consist of small gasoline cars similar to those described for the systems using the overhead contact. These cars will carry several men, light tool equipment and a limited amount of repair parts and fittings for the third rail. One of these cars and a shelter for housing it are to be provided for each ten miles of route. For maintaining electric train operation when sleet is falling on the contact surface of the third rail, cars for applying chlorid of calcium and pilot trains are to be provided. The former are to be made from old passenger coaches by equipping them with tanks for carrying a solution of calcium chlorid, and with a system of piping and outlets for applying the solution to the contact surface of the third rail. The pilot trains may consist of three old passenger coaches, each of which will be provided with a full set of sleet cutting contact shoes. During sleet storms, the calcium chlorid car will be drawn over the road by a steam locomotive and the solution will be applied to the contact surface of the third rail to prevent temporarily the formation of ice or to soften it if already formed. The pilot trains will follow the chlorid car and will scrape off the softened ice so that the shoes of the electric locomotives and cars may be able to make contact. One chlorid car is to be provided for each 25 miles of main track. Since the Chicago & North Western Railway would require a large number of multiple-unit cars, it has been assumed, in preparing the estimates, that these would be used as pilot trains and no additional cost for such equipment has been included.

The amount of rolling equipment required to operate the Chicago & North Western Railway by each system of electric traction, under conditions which obtained in 1912, is shown by table CCCLXVII.

TABLE CCCLXVII. NUMBER OF ELECTRIC LOCOMOTIVES, AND AMOUNT OF MULTIPLE-UNIT EQUIPMENT AND WORK AND INSPECTION EQUIPMENT REQUIRED FOR ELECTRIC OPERATION

(Chicago & North Western Railway)

(Basis of 1912)

Equipment	600-Volt D. C.	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Switching locomotives	94	94	94
Road freight locomotives	15	15	15
Passenger locomotives	42	42	42
Multiple-unit motor cars	159	159	159
Multiple-unit trailer cars	89	89	89
Line inspection cars	9	13	13
Repair trains	0	3	3
Calcium chlorid cars	12	0	0

It will be noted that the locomotive requirements set forth in table CCCLXVII differ from those given for the Chicago & North Western Railway in the estimates of the cost of complete electrification of the entire terminal (section 213.065). This difference is due to the assumption that, since the present estimate is for the electrification of the Chicago & North Western Railway alone, independent of all other roads, the traffic now handled by the Chicago & North Western Railway locomotives on tracks of other railroads will continue to be handled by steam locomotives. The unit costs of equipment for each system, on the basis of 1912, are given in table CCCLXVIII.

TABLE CCCLXVIII. UNIT COSTS OF ELECTRIC LOCOMOTIVES, MULTIPLE-UNIT EQUIPMENT AND WORK AND INSPECTION EQUIPMENT

(Chicago & North Western Railway)

(Basis of 1912)

Equipment	600-Volt D. C.	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Switching locomotives	$28,000	$30,000	$33,000
Road freight locomotives	40,000	42,000	50,000
Passenger locomotives	57,500	59,500	67,500
Multiple-unit motor cars	17,300	20,200	20,100
Multiple-unit trailer cars	10,500	10,400	10,400
Line inspection cars, including tool equipment and shelter	400	475	475
Repair trains, excluding locomotives	......	5,000	5,000
Calcium chlorid cars for removing sleet	1,120	.	.....

The estimated total cost of rolling equipment and the cost of each type of equipment for the several systems under consideration, on the basis of the requirements of 1912, excluding all allowances for contingencies and for engineering, are set forth in table CCCLXIX.

The costs shown by table CCCLXIX represent the costs of rolling equipment on the basis of the requirements of 1912. These have been extended in a manner normal to these estimates (section 212.09), to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those applied to the estimates of the cost of rolling equipment for the entire terminal (section 213.069). The estimated total cost of electric rolling equipment for the Chicago & North Western Railway, on the basis of the requirements of 1922, is as follows:

600-volt direct current	$15,511,865
2,400-volt direct current	16,770,059
11,000-volt alternating current	17,968,142

213.129 Spare Parts: Spare parts for the power station, substations, switching stations, transmission system, contact system, and cars and locomotives, for both the 2,400-volt direct current and the 11,000-volt alternating current systems, have been described in section 213.070. Spare parts to be provided for the Chicago & North Western Railway for either of these systems are to be of the same general character. For the 600-volt direct current system, the necessary spare parts for third rail will be substituted for those required for overhead contact. On account of the greater amount of apparatus required for the 600-volt substations and the greater length of the transmission circuit for this system, the cost estimated for spare parts exceeds that necessary for these items for the other two systems.

The estimated costs of spare parts for each system, on the basis of the requirements of 1912, excluding all allowances for contingencies and for engineering, are given in table CCCLXX.

TABLE CCCLXX. ESTIMATED COSTS OF SPARE PARTS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING

(Chicago & North Western Railway)

(Basis of 1912)

Item	600-Volt D. C.	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
For power station	$17,000	$17,000	$17,000
For substation and switching stations	15,500	12,500	9,500
For transmission line and contact system	3,000	2,000	2,000
For multiple-unit cars and locomotives	44,700	44,700	44,700
Totals	$80,200	$76,200	$73,200

The costs shown by table CCCLXX represent the costs of spare parts on the basis of requirements of 1912. These have been extended in a manner normal to these estimates (section 212.09), to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those applied to the estimated costs of the plant or facility for which spare parts are required. The estimated total cost of spare parts for the Chicago & North Western Railway, on the basis of the requirements of 1922, is as follows:

600-volt direct current	$136,344
2,400-volt direct current	129,232
11,000-volt alternating current	124,018

213.130 Changes and Alterations to Structures: Changes and alterations to structures, required for the installation of the third rail contact conductors, are quite different from those required for overhead contact conductors. For the third rail, changes are necessary to those structures alongside the tracks which encroach upon the proposed standardized location of the third rail contact. With overhead contact, the changes to structures comprise those necessary to

TABLE CCCLXIX. ESTIMATED COSTS OF ROLLING EQUIPMENT FOR ELECTRIC OPERATION, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING

(Chicago & North Western Railway)

(Basis of 1912)

Equipment	600-Volt D. C.	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Switching locomotives	$2,632,000	$2,820,000	$3,102,000
Road freight locomotives	600,000	630,000	750,000
Passenger locomotives	2,415,000	2,499,000	2,835,000
Multiple-unit motor cars	2,750,700	3,211,800	3,195,900
Multiple-unit trailer cars	934,500	925,600	925,600
Line inspection cars	3,600	6,175	6,175
Repair trains	0	15,000	15,000
Calcium chlorid cars	13,440	0	0
Totals	$9,349,240	$10,107,575	$10,829,675

provide a certain minimum clearance for the contact wires above the tracks. Changes required for the 600-volt direct current third rail system on the Chicago & North Western Railway involve the following:

1. Alterations to station platforms.
2. Moving switch machines and boxes.
3. Cutting bridge gusset-plates.
4. Changes in tracks.
5. Changes in other structures.

At station platforms the third rail is to be placed, when possible, on the side of the track opposite the platform, and the platform is to be provided with an extension under which the contact shoes of the rolling equipment may pass. This extension will act as a protection to prevent persons on the platform from touching the contact shoes when a train is standing at the station. When it is not possible, because of local conditions, to locate the third rail on the side of the track opposite the platform, it is to be placed adjacent to the platform and its projection or extension will serve not only to prevent persons on the platform from touching the third rail, but also from touching the contact shoes. Examination has shown that in many cases existing platforms must be modified to provide the necessary clearance for the installation of the third rail or contact shoe protection.

To permit inspection and repairs to switch machines, a gap is to be provided in the third rail where such machines occur. It has been found, however, that many of these machines or other pieces of similar apparatus must be lowered or otherwise modified to give the proper clearance for the contact shoes of the rolling equipment. The cost of the necessary changes to switch machines has been estimated at $10.00 for each No. 4 machine and at $8.00 for each No. 2 machine.

An examination of the clearances on all existing bridges indicates that in some cases it will be necessary to cut the gusset-plates to permit the installation of the third rail, but that in no case will this cutting be sufficient to necessitate the strengthening of the gusset-plates. The unit cost for making these cuts has been estimated at $1.60 each.

There are a few places where the present arrangement of tracks will not permit the installation of the third rail, but a slight change in the track arrangement will usually provide the necessary clearance. In such cases it has been assumed that the necessary changes will be made, and the estimated cost of these changes is included.

Changes in other structures will include such minor changes as lowering of battery tubs, manholes and boxes for air and water connections, moving piping, and cutting back foundations and copings of walls.

The estimated cost of making the necessary changes in structures to provide for the third rail installation, on the basis of the conditions which existed in 1912, is as follows:

Changes to platforms	$63,630
Changes to switch machines	4,210
Changes to bridges	10,650
Changes to tracks	790
Other changes	1,320
Total	$80,600

The changes in structures, required in the case of either the 2,400-volt direct current or the 11,000-volt alternating current systems, consist of altering overhead structures to obtain a minimum clearance of 16 feet, 6 inches. The changes of this kind necessary on the Chicago & North Western Railway have been discussed in section 213.074, and the cost of these will be the same for the independent scheme of electrification for this road as was given in that section as the road's share of the total cost of changes. The estimated cost of changes for each of the overhead contact systems, on the basis of 1912, amounts to $294,000.

Extending these estimated costs of labor and materials for the changes and alterations to structures, on the basis of 1912, by the application of the same factors to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, as set forth in chapter 212, the estimated total cost of changes to structures, on the basis of the requirements of 1922, is as follows:

600-volt direct current	$131,671
2,400-volt direct current	480,288
11,000-volt alternating current	480,288

213.131 Changes in Wire Lines: The changes in wire lines, necessary for electrification of the Chicago & North Western Railway by the 2,400-volt direct current system and the 11,000-volt alternating current system, are of the same character as those discussed in sections 213.076 to 213.078, inclusive. For electrification with the

600-volt direct current system, the changes in wire lines consist only of those required where the transmission circuits parallel the tracks, in which case the required changes will be quite similar to those described for the overhead contact systems.

The estimated costs of labor and materials for changes in wire lines, on the basis of conditions which obtained in 1912, excluding all allowances for contingencies and for engineering, are set forth for the three systems in table CCCLXXI.

TABLE CCCLXXI. ESTIMATED COSTS OF CHANGING WIRE LINES, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING
(Chicago & North Western Railway)
(Basis of 1912)

Item	600-Volt D. C.	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Wire crossings	$ 17,000	$ 36,000	$ 36,000
Parallel pole lines	181,359	210,077	210,077
Totals	$198,359	$246,077	$246,077

The costs shown by table CCCLXXI represent the costs of labor and materials on the basis of the requirements of 1912. These have been extended in a manner normal to these estimates (section 212.09), to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those applied to the estimates of the cost of changes in wire lines for the entire terminal (section 213.080). The estimated total cost of changes in wire lines for the Chicago & North Western Railway, on the basis of the requirements of 1922, is as follows:

600-volt direct current	$324,046
2,400-volt direct current	401,999
11,000-volt alternating current	401,999

213.132 Changes in Signal Systems: The necessary changes in signal systems, for both the 2,400-volt direct current and the 11,000-volt alternating current systems, have been discussed in sections 213.081 to 213.085, inclusive. These changes have been determined according to the needs of the individual railroads for each of the systems of traction, and the figures given in section 213.087 for the Chicago & North Western Railway may be accepted as applying also to the electrification of this railroad alone by either of the overhead contact systems. For the 600-volt direct current system, the necessary changes in the signal system will be practically the same as for the 2,400-volt direct current system, but in addition it will be necessary to provide supports for the signal transmission line circuits.

The unit costs for the several items involved in the signal changes for each of the three systems, on the basis of 1912, are shown by table CCCLXXII.

TABLE CCCLXXII. UNIT COSTS OF CHANGES IN EXISTING SIGNAL SYSTEMS
(Chicago & North Western Railway)
(Basis of 1912)

Item	600-Volt D. C.	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Track circuits	$ 1,400	$ 1,400	$ 1,200
Switches within track circuit limits	400	400	300
Transmission line per mile of duplicate circuit	1,070	950	950
Signal power substations without buildings	11,000	11,000	11,000
Signal power substations with buildings	15,000	15,000	15,000

Applying these unit costs, the costs of labor and materials for the changes in the signal system, on the basis of 1912, have been determined for each of the three systems. Excluding all allowances for contingencies and for engineering, these costs are shown by table CCCLXXIII.

TABLE CCCLXXIII. ESTIMATED COSTS OF CHANGES IN SIGNAL SYSTEMS, EXCLUDING ALL ALLOWANCES FOR CONTINGENCIES AND FOR ENGINEERING
(Chicago & North Western Railway)
(Basis of 1912)

Item	Number	600-Volt D. C.	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4	5
Track circuit	701	$ 981,400	$ 981,400	$ 841,200
Switches	287	114,800	114,800	86,100
Transmission line, miles	84.1	140,447	79,895	79,895
Power units	2	26,000	26,000	26,000
Totals	. . .	$1,262,647	$1,202,095	$1,033,195

The costs shown by table CCCLXXIII represent the costs of labor and materials on the basis of the requirements of 1912. These have been extended in a manner normal to these estimates (section 212.09), to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those applied to the estimated cost of changes in signal systems for the entire terminal (section 213.088). The cost of changes in signal systems for the Chicago & North Western Railway, on the basis of the requirements of 1922, is as follows:

600-volt direct current	$2,210,036
2,400-volt direct current	2,104,051
11,000-volt alternating current	1,808,422

213.133 Cost of Transfer Yards and Rearranging Motive Power Terminals: The various factors involved in the cost of transfer yards and rearranging motive power terminals consist of facilities to be abandoned, the removal of facilities and the construction of new facilities. The character of these facilities has been discussed in sections 213.089 to 213.095, inclusive.

In the plan of electrification of the Chicago & North Western Railway, the abandonment of steam locomotive facilities is involved at the following locations:

1. Chicago Avenue Yard.
2. 40th Avenue Yard.
3. Halsted and Kinzie streets.
4. Weber Yard.
5. Waukegan.

The present facilities at the Wood Street Yard are to be retained for the care of steam locomotives of the Chicago & North Western Railway which are required for handling traffic on the tracks of other railroads.

New facilities for steam locomotives, electric locomotives or multiple-unit equipment are to be provided at the following locations:

1. Chicago Avenue Yard.
2. Wood Street Yard.
3. 40th Avenue Yard.
4. Elmhurst.
5. Weber Yard.
6. Proviso.
7. Desplaines.
8. Niles Center.
9. Waukegan.

Transfer yards are to be provided at the following locations:

1. Proviso.
2. Desplaines.
3. Niles Center.
4. Waukegan.

The estimated cost, present or release value, and salvage value of the property subject to abandonment are as follows:

First cost of property	$508,394
Present value of property	352,200
Salvage value of property	29,380

The value of the property to be abandoned is not included as a part of the cost of electrification.

The first cost of new facilities to be provided for the Chicago & North Western Railway will be the same as the estimated cost for this road as a part of the entire electrification, namely, $3,498,000. This represents the estimated cost of labor and materials on the basis of the requirements of 1912. This has been extended in a manner normal to these estimates (section 212.09), to cover growth, contingencies, engineering, and interest, insurance and taxes during construction, the factors of extension being the same as those applied to the estimated cost of new terminal facilities for the entire terminal (section 213.096). The total cost, thus obtained, of the new terminal facilities for the Chicago & North Western Railway, on the basis of the requirements of 1922, is the same for all systems of electrification and amounts to $6,632,838.

213.134 Released Rolling Equipment: The amount of released rolling equipment will be the same for all systems of traction under consideration. In determining the amount of equipment to be released on the Chicago & North Western Railway, the general methods outlined in sections 213.097 to 213.102, inclusive, have been followed. Under the plan of operation devised, the tracks of the Chicago & North Western Railway only are to be electrified, and the traffic over the tracks of other railroads by the locomotives of the Chicago & North Western Railway is to be handled by steam locomotives. The amount of equipment to be released, therefore, is not as great as has been assumed for the Chicago & North Western Railway in the plan of complete electrification for the Chicago terminals.

The amount of equipment to be released for each class of service is set forth in table CCCLXXIV with the estimated first cost of each class of equipment.

TABLE CCCLXXIV. ESTIMATED TOTAL FIRST COST OF EQUIPMENT TO BE RELEASED
(Chicago & North Western Railway)
(Basis of 1912)

Service	No.	Unit Cost	Total Cost
1	2	3	4
Through passenger locomotives	8	$18,500	$ 148,000
Road freight locomotives	3	18,500	55,500
Transfer locomotives	22	15,500	341,000
Switching locomotives	84	13,000	1,092,000
Suburban passenger locomotives	44	12,500	550,000
Suburban passenger cars	325	5,200	1,690,000
Total			$3,876,500

These amounts, however, do not represent the credit to electrification due to the release of the equipment since they are estimated first costs. The present or release value of the equipment to be released has been determined by using the unit release values presented in sections 213.103 and 213.104. The estimated total release value of each class of equipment to be released, under the conditions which obtained in 1912, is shown by table CCCLXXV.

TABLE CCCLXXV. ESTIMATED RELEASE VALUE OF EQUIPMENT
(Chicago & North Western Railway)
(Basis of 1912)

Service	No.	Present Value per Unit	Total Present Value
1	2	3	4
Through passenger locomotives	8	$11,000	$ 88,000
Road freight locomotives	3	12,000	36,000
Transfer locomotives	22	9,300	204,600
Switching locomotives	84	7,800	655,200
Suburban passenger locomotives	44	5,000	220,000
Suburban passenger cars	325	500	162,500
Total			$1.366,300

The estimates of the release value of equipment of the Chicago & North Western Railway have been extended by applying a factor of 21 per cent to cover growth, as has been done in the case of the estimates for the entire terminal, with the following result:

Estimated total value of equipment to be released, December 31, 1922	$1,653,223

213.135 Summary of Total Installation Cost of Three Systems of Electrification for a Single Road (Chicago & North Western Railway): The several items making up the total installation costs of electrification of the Chicago & North Western Railway by each of three systems have been determined as set forth in the preceding sections. A summary of the total cost, on the basis of the requirements of 1922, is presented as table CCCLXXVI.

To obtain the net cost of electrification, it is necessary to deduct from the installation or gross cost as set forth in table CCCLXXVI, the salvage on abandoned property or on property released from local transportation service. Since values of these items of credit have already been determined, as set forth in the preceding sections, it is not necessary to the purpose of this summary to include them here.

213.136 Ratios between Installation Costs of the Three Systems for the Chicago & North Western Railway: It will be seen from table CCCLXXVI that the ratios between the installation costs of electrification for the Chicago & North Western Railway are as follows:

$$\frac{\text{Cost by 600-volt third rail system}}{\text{Cost by 2,400-volt overhead system}} = \frac{40{,}044{,}745}{39{,}299{,}600} = 1.01896$$

$$\frac{\text{Cost by 600-volt third rail system}}{\text{Cost by 11,000-volt overhead system}} = \frac{40{,}044{,}745}{37{,}525{,}930} = 1.06712$$

213.137 Statement of Installation Costs of the Three Systems for the Entire Terminal, as Determined by the Application of Ratios Found to Exist for a Single Road: The estimated total installation cost of electrification to the extent covered by the plan of the Committee is shown in table CCCXLVIII of section 213.109 to be $191,666,808 for the 2,400-volt direct current overhead contact system, and $187,902,916 for the 11,000-volt alternating current overhead contact system. It has been assumed that the cost of electrification, under the Committee's plan, by the 600-volt direct current third rail system, will bear the same ratios to the costs by the other two systems under consideration as have been found to exist in the case of the costs of electrification determined for the Chicago & North Western Railway alone. These ratios are presented in section 213.136. The cost of electrification by the 600-volt direct current third rail system, as derived from the estimated cost of the 2,400-volt direct current overhead contact system, will be 1.01896 x $191,666,808 or $195,301,000, and as derived from the

TABLE CCCLXXVI. SUMMARY OF TOTAL INSTALLATION COST OF ELECTRIFYING THE CHICAGO & NORTH WESTERN RAILWAY BY THREE SYSTEMS
(Dec. 31, 1922)

Item	600-Volt D. C.	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Power station	$ 3,863,402	$ 3,863,402	$ 3,866,565
Transmission system	974,863	279,743	267,475
Substations	1,958,773	1,971,409	538,205
Switching stations	142,616	196,934	80,912
Contact system	7,106,749	5,309,742	4,311,396
Bridge warnings	0	108,554	108,554
Return circuit	1,007,404	1,007,211	735,358
Prevention of inductive effects and electrolysis	0	0	157,620
Telephone patrol line	44,138	44,138	44,138
Electric locomotives, multiple-unit equipment, work and inspection equipment	15,511,865	16,770,059	17,968,142
Spare parts	136,344	129,232	124,018
Changes in structures	131,671	480,288	480,288
Changes in wire lines	324,046	401,999	401,999
Changes in signal systems	2,210,036	2,104,051	1,808,422
Removal and re-establishment of steam locomotive terminals	6,632,838	6,632,838	6,632,838
Totals	$40.044,745	$39.299,600	$37.525,930

estimated cost of the 11,000-volt alternating current overhead contact system, will be 1.06712 x $187,902,916 or $200,515,000. The mean of these two values is $197,908,000, and this amount may be taken as a fair approximation of the installation cost of electrifying the entire terminal by the 600-volt direct current third rail system. A summary of these costs is as follows:

600-volt direct current	$197,908,000
2,400-volt direct current	191,666,808
11,000-volt alternating current	187,902,916

A SUMMARY OF COSTS

213.138 Capital Requirements Including Precipitated Costs and Costs Due to Extensions not Covered by the Committee's Plan: Assuming such departure from the plan of the Committee as is believed by the railroads to be essential, and including the costs of changes and betterments which will be precipitated by electrification, the probable total capital requirements, based on the use of the 11,000-volt alternating current system, will be increased as shown by table CCCLXXVII.

TABLE CCCLXXVII. PROBABLE TOTAL CAPITAL REQUIREMENT FOR THE ELECTRIFICATION OF THE CHICAGO RAILROAD TERMINALS, 11,000-VOLT A. C. SYSTEM
(Dec. 31, 1922)

Item	Amount
Net cost incident to the development of the minimum plan as estimated by the Committee (section 213.139)	$178,127,230
Precipitated cost and cost due to extensions of the plan as estimated by the railroads (section 213.116)	96,313,400
Estimated total capital requirements	$274,440,630

213.139 Costs, Assuming the Work to be Limited to the Requirements of a Minimum Plan: A summary of the costs of equipping the railroad terminals of Chicago for electric operation under the plan of the Committee is set forth by the paragraphs which follow. It should be remembered that these plans deal with a definite extent of trackage and traffic (chapters 209 and 211); that they provide for growth in the existing railroad establishment to the end of the year 1922; that they do not cover any general revision of the terminals as they existed in 1912; and that they are based upon the joint development of all facilities required for the generation and transmission of electric energy, but not the joint use of tracks nor the joint operation of trains except in so far as such operation may already prevail.

The estimated total cost, by items, of the 2,400-volt direct current system and the 11,000-volt alternating current system, under the plan of the Committee, is summarized in table CCCLXXVIII.

TABLE CCCLXXVIII. ESTIMATED TOTAL COST OF ELECTRIFICATION BY ITEMS, ALL ROADS
(Dec. 31, 1922)

Item	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3
Power station	$ 10,213,458	$ 10,302,104
Transmission system	1,305,444	1,618,693
Substations	5,660,352	2,024,736
Switching stations	1,522,285	573,073
Overhead contact system	33,895,276	28,141,188
Bridge warnings	1,071,989	1,071,989
Return circuit	6,069,899	4,446,033
Prevention of inductive effects and electrolysis	....	996,727
Telephone system	272,052	272,052
Electric locomotives, multiple-unit equipment, work and inspection equipment	84,003,395	91,703,557
Spare parts	502,725	485,343
Changes in overhead structures	834,261	834,261
Changes in wire lines	2,028,007	2,028,007
Changes in signal system	6,993,919	6,111,407
Removal and re-establishment of locomotive terminals and new facilities	37,293,746	37,293,746
Totals	$191,666,808	$187,902,916

The estimated total cost of electrification, December 31, 1922, by the 600-volt direct current, the 2,400-volt direct current and the 11,000-volt alternating current systems, as determined under the Committee's plan, is set forth as follows:

600-volt direct current	$197,908,000
2,400-volt direct current	191,666,808
11,000-volt alternating current	187,902,916

The gross cost of the electrification, the credits due to salvage of property and the net cost of electrification for each of the three systems are set forth in table CCCLXXIX.

The gross cost of electrifying the terminals by the 2,400-volt direct current system and the 11,000-volt alternating current system, and certain deductions to be made from the gross cost to show the

TABLE CCCLXXIX. GROSS COST, CREDITS AND NET COST OF ELECTRIFICATION, ALL ROADS
(Dec. 31, 1922)

Item		600-Volt D. C.	2,400-Volt D. C.	11,000-Volt A. C.
1		2	3	4
Cost of electrification, including all details necessary to make up the new establishment and all changes in existing facilities made necessary by the introduction of new equipment but not including any general revision of terminals		$197,908,000	$191,666,808	$187,902,916
Salvage from facilities to be abandoned or utilized for other purposes, December 31, 1916	$ 278,880			
Salvage value of rolling equipment (cars and steam locomotives) to be released	9,496,806			
Total salvage		9,775,686	9,775,686	9,775,686
Net cost of electrification		$188,132,314	$181,891,122	$178,127,230

net changes in property values, are given in table CCCLXXX.

TABLE CCCLXXX. GROSS COST OF ELECTRIFYING THE CHICAGO RAILROAD TERMINALS, WITH CHANGES IN PROPERTY VALUES

(Dec. 31, 1922)

Item	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3
Gross cost of electrification including necessary changes in existing establishments	$191,666,808	$187,902,916
Changes in overhead structures....$ 831,261	....	....
Changes in wire lines 2,028,007	....	....
Changes in signals, 2,400-volt d. c. 6,993,919	....	....
Changes in signals, 11,000-volt a. c. 6,111,407	....	....
Salvage from facilities to be abandoned or utilized for other purposes 278,880	....	....
Salvage value of rolling equipment (cars and steam locomotives) to be released 9,496,806	....	....
Total deductions	19,631,873	18,749,361
Changes in property values	$172,034,935	$169,153,555

First cost, release value and salvage value of steam locomotive facilities to be abandoned, and the net value of terminal property which would be dissipated, are set forth as follows:

First cost of facilities to be abandoned (section 213.092)		$3,502,530
Present value of facilities to be abandoned or adapted to other uses (section 213.092)	$2,596,837	
Salvage from facilities to be abandoned or adapted to other uses (section 213.092)	278,880	
Net value (1916–1922) of property dissipated		$2,317,957

The net total cost of electrification for each railroad, as determined from values presented in the preceding sections of this chapter, for the 2,400-volt direct current system and the 11,000-volt alternating current system, is summarized in table CCCLXXXI.

213.140 Conclusions Concerning the Cost of Complete Electrification of the Chicago Railroad Terminals: The facts already presented in this chapter, concerning the cost of complete electrification of the Chicago railroad terminals, may be summarized as follows:

1. The direct cost, including the cost of all electric equipment and of all changes in the existing establishment necessary to admit the new equipment and the new operation for an extent of trackage sufficient to make operation practicable, on the assumption that all steam locomotives are to be eliminated from the city of Chicago, amounts to $178,127,230.

2. The direct cost of electrification will, in the actual working out of the problem, be in excess of the estimates set forth by the previous item, due to the fact that the conditions which have been assumed as a basis for the estimates will not be observed. Inability on the part of the railroads to proceed with the work of electrification as a joint problem, and a disposition on their part to regard electrification as something more than a means in smoke abatement, will extend the amount of trackage involved and will lead to the adoption of a more expensive procedure in installation.

TABLE CCCLXXXI. NET TOTAL COST OF ELECTRIFICATION, BY RAILROADS AND BY SYSTEMS

(Dec. 31, 1922)

Railroad	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3
Atchison, Topeka & Santa Fe Ry.	$ 4,031,758	$ 4,028,852
Baltimore & Ohio R. R.	3,909,831	3,889,521
Baltimore & Ohio Chicago Terminal R. R. ...	4,211,111	3,976,592
Calumet, Hammond & Southeastern R. R. ..	208,747	214,390
Chesapeake & Ohio Ry. of Indiana	650,732	708,213
Chicago & Alton R. R.	3,175,505	3,230,069
Chicago & Calumet River R. R	309,288	302,229
Chicago & Eastern Illinois R. R.	2,087,193	2,172,491
Chicago & Erie R. R.	1,307,633	1,317,194
Chicago & North Western Ry.	35,403,102	34,367,826
Chicago & Western Indiana R. R. and the Belt Ry. of Chicago	9,551,957	8,795,588
Chicago, Burlington & Quincy R. R.	10,520,849	10,308,399
Chicago Great Western R. R.	1,869,770	1,938,597
Chicago, Indiana & Southern R. R.	969,816	956,972
Chicago, Indianapolis & Louisville Ry.	1,390,550	1,466,289
Chicago Junction Ry.	4,586,820	4,437,384
Chicago, Milwaukee & St. Paul Ry.	14,036,282	13,936,034
Chicago River & Indiana R. R.	122,571	104,887
Chicago, Rock Island & Pacific Ry.	9,057,151	8,797,061
Chicago Short Line Ry	216,662	223,212
Chicago Union Transfer Ry.	183,684	163,847
Chicago, West Pullman & Southern R. R.	559,686	571,204
Elgin, Joliet & Eastern Ry.	3,043,104	3,038,284
Grand Trunk Western Ry.	3,857,173	3,890,365
Illinois Central R. R.	20,730,056	19,877,013
Illinois Northern Ry.	577,246	569,917
Indiana Harbor Belt R. R.	1,035,650	961,229
Lake Shore & Michigan Southern Ry .	10,789,541	10,492,711
Michigan Central R. R.	4,528,166	4,566,265
Minneapolis, St. Paul & Sault Ste. Marie Ry.	863,553	950,200
New York, Chicago & St. Louis R. R.	3,462,346	3,480,805
Pere Marquette R. R.	1,790,211	1,875,878
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	6,562,877	6,536,482
Pittsburgh, Ft. Wayne & Chicago Ry.	10,091,375	9,737,262
Pullman Railroad	784,259	743,549
Wabash Railroad	5,414,867	5,500,419
Totals	$181,891,122	$178,127,230

3. The capital requirements involved by electrification will be greater than the cost of electrification, due to the fact that changes and betterments in the existing establishment, which otherwise might be long deferred, will need to be made a part of a program to be executed prior to or concurrently with electrification. These precipitated costs will vary greatly for different roads.

4. An examination by railroad companies of the cost to them, which would arise in the manner set forth and which would be in excess of the cost estimated by the Committee, shows that such costs will be approximately $96,313,400.

5. The total capital requirements, which will be imposed by complete electrification of the Chicago railroad terminals, will therefore amount to $274,440,630.

PART III

A STUDY OF RESULTS WHICH ARE TO BE ANTICIPATED FROM ELECTRIFICATION IN CHICAGO

301. RAILROAD OPERATING EXPENSES AS AFFECTED BY ELECTRIFICATION*

SYNOPSIS: This chapter presents a discussion of the changes which electrification will introduce in operating conditions, and sets forth the effect of these changes upon the expense of operating the railroads involved.

301.01 Changes in Operating Conditions: The electrification of Chicago's railroad terminals will introduce a new system of operation over all electrified trackage. Those railroads which have trackage entirely within the city will, under the plan of the Committee, discontinue all use of steam locomotives. Railroads operating beyond the proposed limits of electrification will, however, continue to use steam locomotives after electrification has been achieved; they will operate electrically all that part of their service carried on within the city of Chicago and its vicinity, while beyond the electrified zone they will continue to operate by steam. Railroads so affected must establish transfer stations at which motive power may be changed, and they must also meet new conditions involving changes in schedules and in operating conditions outside of the electrified zone.

The changes in operating conditions which will result from complete electrification of Chicago's railroad terminals are therefore of a threefold character:

1. Those incident to the introduction of electric operation on trackage within the proposed limits of electrification as defined by roads (chapter 209).
2. Those incident to the operation of transfer stations at which change of motive power is to be made.
3. Those resulting from the shortening of the steam operated divisions at present terminating in Chicago.

These changes will introduce changes in operating expenses, the nature and extent of which will be influenced by the character of the electric installation. Thus, an installation of electric facilities in accord with plans designed to promote high efficiency in operation will permit train movements on electrified trackage at lower expense than a similar installation, in the design of which efficiency in operation is not made a governing consideration.

The substitution of electric operation for steam operation does not always result in operating economies. If conditions are such as will supply a favorable setting for the electric equipment and if the various factors making up the electric installation are chosen with due regard to their

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* The original records from which this chapter is prepared are preserved in the Archives of the Committee, Vols. K 1 to K 5, inclusive.

efficiency in operation, it is possible to secure some saving as compared with the costs of steam operation; whereas, if the reverse conditions prevail, electric operation may be more expensive than steam operation.

The extent of trackage involved by the Committee's plan of electrification has been determined on the assumption that the work will proceed as a means in smoke abatement. While the considerations underlying the extent of the plan have already been fully set forth (chapter 209), it is necessary here to note that the plan of the Committee restricts the extent of electrified trackage to the minimum limits consistent with practicability in operation. The limits provide, in the case of most roads, for the termination of electric operation as soon as practicable after the boundaries of the city are passed. An extension of these limits to embrace an entire operating division would constitute an expansion of the Committee's plan, but it would provide greater freedom in the movement of equipment, would eliminate the cost of maintaining new transfer stations and would in many ways promote efficiency in the operation of electric service. The inclusion of an entire railroad division in the plan of electrification would make a far more satisfactory arrangement from an operating point of view than the plan proposed by the Committee. But any plan to secure the operating result which can only be had from the electrification of an entire railroad division would greatly increase installation costs as compared with those which have been estimated by the Committee.

The extent and character of the traffic to be handled, as measured by the energy required, have been set forth in preceding pages of this report (chapter 211). These are factors which, as used in the study of operating results, apply to the whole terminal. The Committee's plan provides for a single source of power, a single system of transmission lines and a single system of substations for all the railroads in the terminal. It cannot be assumed that all roads possess, or that any single road possesses, the same density or uniformity of flow of traffic as does the entire terminal. Different roads vary greatly in these respects. Different portions of the same road and different services of the same road present many varying conditions. Individual power systems for each of the roads would not have the same favorable load conditions which are shown to result from the supply by a single power system of the combined power requirements of all roads. The single power generating and distributing system meets the requirements for high efficiency in operation as well as low cost in installation. A single power station serving all roads will permit the delivery of electric energy at a lower unit cost than individual power stations for individual roads, and a single system of substations will cost less for operation than individual systems for each road. The plan of the Committee may, therefore, be accepted as that which, within the limits affected, will promote maximum operating efficiency. Obviously, any departure from this plan, which might involve the establishment of individual facilities for individual roads, would result in an increase in operating expenses over those estimated by the Committee. In the discussion which follows, all of this is welded into the summarization which reflects the operations of the entire terminal. The conclusions concerning operating expenses must be accepted merely for what they represent. If the electrification of the entire terminal tends to reduce such expenses, it does not necessarily follow that the electrification of individual roads will produce similar results; that will depend upon conditions peculiar to the individual road. The Committee's problem is a terminal problem, and this fact has justified the Committee in ignoring individual roads in its study of operating expenses.

The preceding statements will serve to show the dependence of operating results upon the extent and character of the installation plans. The economies predicted by the analysis which follows are dependent upon adherence in installation to the plan already set forth. Any departure from the plan of the Committee whereby the operating procedure under electrification will become less efficient will reduce this margin of gain and may entirely eliminate it or even change it to an operating loss.

CHANGES IN OPERATING EXPENSES ON TRACKAGE WITHIN THE PROPOSED LIMITS OF ELECTRIFICATION

301.02 Character of Changes in Operating Expenses on Electrified Trackage which will

Result from Electrification: The elimination of the steam locomotive from the railroad terminals of Chicago and the introduction of an electrically operated service over the existing trackage will effect changes in operating expenses. Some of the present items of expense, such as those relating directly to the operation and maintenance of the steam locomotive, will be eliminated and new items of expense, including those incident to the maintenance and operation of the power station, substations and contact system, will be introduced. In attempting to formulate an estimate of the extent of these changes, consideration has been given only to those factors which relate directly to the changed conditions of operation. No account is taken of the possible effect of electric operation upon the volume of traffic. No changes are proposed in the present arrangement of terminals nor in the existing schedules of train movements. The purpose is to compare the expense of the present steam operated service with that of an electric service of equal volume and of equal quality, over a definite extent of trackage.

301.03 Extent of the Trackage and Traffic Affected by Electrification: The trackage involved in the proposed change from steam to electric operation amounts to a total of 3,439.14 track miles. This includes main, yard and industrial tracks as defined by railroads elsewhere in this report (chapter 209).

The average daily service performed on this trackage during the Committee's statistical year, 1912, expressed in locomotive-miles, is shown by table CCCLXXXII.

TABLE CCCLXXXII. EXTENT OF TRAFFIC AFFECTED BY ELECTRIFICATION OF THE CHICAGO TERMINALS
(Basis of 1912)

Service	Locomotive-Miles	Per Cent of Total
1	2	3
Through passenger	14,759	22.22
Suburban passenger	11,614	17.49
Road freight	5,369	8.08
Yard switching	24,752	37.27
Yard transfer	9,921	14.94
Totals	66,415	100.00

301.04 Methods Employed in Determining the Effect of Electrification upon Operating Expenses: The proposed change from steam to electric operation in the Chicago terminals will affect various items of expense incident to railroad operation. These items were early determined by conferences between the officials of various railroads and members of the Committee's staff. It was then sought to determine the amount chargeable, for operation, to each of these affected accounts by each of the railroads during the Committee's statistical year, 1912. This gave the cost, under affected accounts, of steam operation over the trackage to be electrified. The corresponding charges to these affected accounts, assuming electric operation over the same trackage and for the same service, were then determined by methods hereinafter set forth. The difference in the expense as thus set forth, item by item, for steam and for electric operation was accepted as the credit or debit in operation resulting from electrification. The designation of items follows the Interstate Commerce Commission's classification of operating accounts now in general use among the railroads.

Detailed reports covering their expenses for the year 1912 were furnished by 25 of the 39 railroad companies operating within the Area of Investigation (chapter 103), the limits of which differ from the proposed limits of electrification as defined by roads (chapter 209). The total annual expenditure of each of the 25 roads under each account affected was pro-rated among the different services on the basis of the locomotive-mileage performed by each railroad in each service, the services recognized being:

1. Yard service (including freight and passenger transfer services).
2. Road freight service.
3. Through passenger service.
4. Suburban passenger service.

The amounts charged to each service were tabulated for the 25 roads for each account, and the totals thus obtained were divided by the total number of locomotive-miles performed by the 25 roads in the service in question to obtain an average unit expenditure per locomotive-mile for each service under each account. The units of expense thus obtained were applied to the locomotive-mileage performed by each of the 37 railroads involved in the plan of electrification. This process served to give the total amount chargeable to each affected account, for each service of each railroad, covering steam operation in 1912 within the proposed limits of electrification.

The locomotive-mile has been employed as a unit of service in the determination of operating expenses, except in the case of a few accounts to which the application of other units was considered preferable because of the nature of the expense involved. In instances in which other units have been employed, explanation is made in the account analyses presented in the sections which follow. The locomotive-mile was selected as a unit because the change from steam to electric operation will involve little, if any, change in the operating cost of train service back of the locomotive.

In the preparation of estimates of the expense of electric operation, each account has been studied, a form of analysis developed and the effect of the change estimated. In dealing with some accounts it was possible to base estimates upon a definite schedule of labor and materials involved, while in dealing with others the absence of reliable data covering the expense of conducting electric traction required an arbitrary adoption of unit expenses. These, in all cases, were formulated in conference with the Committee's consulting electrical engineers. Estimates of operating expenses cover each of three systems of electric traction, as follows:

1. A system employing direct current at 2,400 volts with overhead contact.
2. A system employing alternating current at 11,000 volts with overhead contact.
3. A system employing direct current at 600 volts with third rail contact.

In the cases of the 2,400-volt direct current and the 11,000-volt alternating current systems, the expenses were estimated for the entire service, within the proposed limits of electrification, of the 25 roads which reported, and the amounts thus obtained were reduced to units of expense which were then applied to the total service within the limits of electrification of all roads involved. Amounts thus determined for the entire terminal were pro-rated to the different classes of service on a locomotive-mile basis. In the case of the 600-volt direct current third rail system, the estimated unit operating expense under each affected account of electric operation on a single representative road[*] was determined for each class of service. It was assumed that the operating expense under affected accounts, for the 600-volt third rail operation of the entire service of all roads within the proposed limits of electrification, would bear the same ratio to the expense of operating the 600-volt system on the single representative road as the total present expense, under the accounts affected, of conducting steam service on all roads within the limits of electrification bears to the present operating expense of steam service, under the affected accounts, on the single representative road. This process was applied to each service. The total operating expense, under affected accounts, for the 600-volt third rail system was then obtained by multiplying the unit determined in the manner explained by the mileage in the service to which it applied, the total expense being the sum of the expenses for each class of service. This total expense was then divided by the total number of locomotive-miles performed in all services to give the average unit operating expense applicable to all services for electric operation within the proposed limits of electrification.

In compiling the statistical facts and estimates presented in the sections which follow, it has been assumed that the change from steam to electric operation will involve no change in rates of pay nor in the number of men employed on each train and on each locomotive, except in the case of multiple-unit passenger service, which will include all passenger service beginning and ending within the electrified limits. Only one man, a motorman, is required for the control of motive power on a multiple-unit train. The rate of pay for motormen has, in these estimates, been fixed at $4.675 for each 100 miles or less. This rate is in agreement with the rates now paid the motormen operating gasoline motor cars on steam railroads. It is assumed that the multiple-unit trains will carry the same number of trainmen now carried on suburban passenger trains back of the steam locomotive, and that the pay of these trainmen will remain unchanged.

The final estimates of the expense of both steam and electric operation, on the basis of the volume of service performed in 1912, have

[*] The Chicago & North Western Railway, the road selected, is one of the largest of those affected and is, in respect to variety of service performed, representative of the operating conditions of the whole terminal. It also presents fewer physical obstacles to the installation and operation of a third rail system than most of the other roads, a circumstance due to the fact that most of its tracks are elevated or protected by fences. Owing to these conditions, the estimated expense of third rail operation for all roads, as hereinafter set forth, may be slightly lower than would develop in actual operation, but for purposes of comparison with the expense of electric operation by either of the other two systems and with that of the present steam operation the estimates will not be misleading.

been extended in the manner normal to all estimates of the Committee (section 212.09), to cover the increase in the volume of traffic until the end of the year 1922 when, for the purpose of these estimates, it is assumed that the work incident to the installation of the electric traction system will be completed.

301.05 Analyses of Expenses Covered by the Operating Accounts Affected by the Proposed Change from Steam to Electric Operation: In the following analyses, by accounts, of the effect of the change from steam to electric operation, it will be noted that no attempt has been made to determine the total cost of steam operation nor to estimate that of electric operation. Only such accounts as will be affected by electrification are evaluated. The initial premise upon which the figures have been developed assumes also that there will be no change whatever, as a result of electrification, in the volume of traffic now handled nor in the schedules by which train movements are governed. In other words, the proposed electric service, for which estimates of operating expenses are presented, will be equivalent in every respect to the present steam service except as to the motive power employed for propelling the trains.

No account is taken, either in these analyses of operating expenses or in the summary of the net effect of the change, of the interest on the increased investment due to the installation of the electric system of traction nor of depreciation of equipment, such charges being elsewhere considered (chapter 401).

*I. Maintenance of Way and Structures**

Account No. 1—Superintendence: The change from steam to electric operation will involve no change in the total expenditures under this account. The expense of new officers, if any, who will be required for superintendence under electric operation will be approximately equivalent to that of present officers who will not be required subsequent to the change.

Account No. 2—Ballast: The quantity of ballast required and the cost of placing it will be the same for electric operation as for steam operation, and there will be no change in the amount of the expenditures chargeable to this account.

Account No. 3—Ties: The installation of the 2,400-volt direct current or of the 11,000-volt alternating current systems of traction will involve no change in the expenses chargeable to this account. The installation of the third rail 600-volt direct current system of traction will involve the use, at intervals in the track, of ties of greater length than the standard tie used at present. The longer tie is required to provide a support for the standards of the third rail. Accepted standards of construction employ long ties 6 by 8 inches by 9 feet, 4 inches, spaced approximately at 10-foot intervals, so that every fifth tie in the present tracks will be replaced by a long tie. With the third rail installation, therefore, the increased cost of these ties will constitute an added maintenance expense chargeable to this account. It is assumed that the longer tie to be used for the third rail installation will be of the same quality as the present No. 1 tie.

Reports made by 13 railroads, operating during 1912 a total of 2,956 miles of track within the Area of Investigation, show the cost of ties used in the maintenance of their tracks to be $134.68 per mile of track, this amount representing the cost of the ties f. o. b. cars at Chicago. On the average, 184 ties per mile of track were required for maintenance. The average cost of No. 1 ties was $0.744 each and of No. 2 ties, $0.72 each.

The present No. 1 standard tie is 6 by 8 inches by 8 feet in dimensions, and the cost per lineal foot is $0.093. The longer tie which, in the third rail installation, will be substituted for every fifth tie, is to be of the same cross-section and of the same quality as the standard No. 1 tie but will be 1 foot, 4 inches, longer. This additional length, at the average price of $0.093 per lineal foot for the standard No. 1 tie, will make the average cost of long ties $0.868 each. On the basis of the average annual maintenance requirement of 184 ties per mile of track, as shown by the reports of the 13 roads covering operation during 1912, this added cost for long ties will effect an increase on the average in the cost of 37 ties per mile of track. The total increase per mile of track will therefore be $4.59, or 3.4 per cent

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* Classification of operating expense accounts as prescribed by the Interstate Commerce Commission for steam railroads, effective July 1, 1908.

above the present expense chargeable to this account.

An extension of this unit increase to cover the trackage within the proposed limits of electrification of the Chicago & North Western Railway, which has been used as the basis for determining the operating expense under the third rail system of traction, yields results as shown by table CCCLXXXIII.

TABLE CCCLXXXIII. ESTIMATED ANNUAL INCREASE IN EXPENDITURES UNDER ACCOUNT No. 3—TIES. 600-VOLT D. C. OPERATION ON THE CHICAGO & NORTH WESTERN RAILWAY

(Basis of 1912)

Miles of Track	Steam Operation		Estimated Annual Cost of Ties with 600-Volt D. C. Installation		Increase Due to 600-Volt D. C. Installation	
	Per Mile	Total	Per Mile	Total	Per Mile	Total per Annum
1	2	3	4	5	6	7
532	$134.68	$71,649	$139.27	$74,092	$4.59	$2,443

The total expense under Account No. 3 for all roads for 1912 was $463,183. This expense is divided by services as follows:

Through passenger	$102,919
Suburban passenger	81,011
Road freight	37,425
Yard and transfer	241,828
Total	$463,183

Account No. 4—Rails: The introduction of electric traction under steam railroad conditions need not necessarily involve any change in the standard track rails used for steam traction. The estimates of the Committee covering installation cost and operating expense of any of the electric traction systems proposed, contemplate the use of the present track rails after electrification. A study of the expense of maintaining rails under electric traction does not indicate that the expenditures chargeable to this account will be affected by electric traction. Under electric operation elsewhere, it has not been apparent that the wheel loads and other strains imposed upon the track by electric locomotives are different in their effects from those due to steam locomotives.

Account No. 5—Other Track Material: The expenditures chargeable to this account will not be affected by the installation and operation of any of the electric traction systems proposed by the Committee.

Account No. 6—Roadway and Track: The expenditures per track mile chargeable to this account will not be affected by the installation and operation of either the 2,400-volt direct current or the 11,000-volt alternating current system of traction. The installation and operation of the 600-volt direct current third rail system will, however, involve an increase in expense under this account, due to the fact that third rail construction will require greater caution on the part of track laborers and consequently will result in a reduction in efficiency and in the amount of work performed by each man employed.

Definite quantitative figures relating to the increased unit expense under this account are difficult to obtain. Opinions of operating officers of the New York Central, Pennsylvania, Long Island and the West Jersey & Seashore roads, all of which employ the third rail system, are to the effect that there is generally a reduction in the amount of work per man and a consequent increase in expense, due to the proximity of the third rail to the track rails.

Based upon reports of engineers experienced in track maintenance and upon the studies and investigations of the Committee's staff, percentage increases in this account have been fixed as follows:

	PER CENT
Track laying (Account No. 6-A)	20
Surfacing (Account No. 6-B)	10
Repairing (Account No. 6-C)	10

From reports furnished by the railroads it was determined that the average labor cost of replacing cross ties in 1912 was $0.30 per tie and that the cost of applying other track material under this account, such as maintenance ballast, rail joints and spikes, was $15.65 per mile of track per annum. Thus, in 1912, the total average annual labor cost per mile of track under this account, on the basis of the maintenance requirements of 184 ties per mile (see analysis of Account No. 3), was $70.85. The analysis of the facts indicated that this average expenditure was apportioned among the three secondary accounts mentioned, as follows:

	PER CENT	AMOUNT
Track laying (Account No. 6-A)	50	$35.43
Surfacing (Account No. 6-B)	40	28.34
Repairing (Account No. 6-C)	10	7.08
Total	100	$70.85

This average annual maintenance expense per mile of track is based upon the reported expenditures for 1912, covering all classes of track, including main track, yard track and sidings.

As stated, the installation and operation of the third rail traction system will involve an increase of 20 per cent in the expense of track laying (Account No. 6-A), of 10 per cent in the cost of surfacing (Account No. 6-B) and of 10 per cent in the cost of repairing (Account No. 6-C). The added expense per mile of track for maintenance under Account No. 6, due to third rail operation, will therefore, on the basis of the conditions existing in 1912, be as follows:

	PER CENT	AMOUNT
Track laying (Account No. 6-A)	20	$7.085
Surfacing (Account No. 6-B)	10	2.834
Repairing (Account No. 6-C)	10	0.708
Total		$10.627

The application of this unit of increase to the entire trackage within the proposed limits of electrification of the Chicago & North Western Railway yields the results which are shown by table CCCLXXXIV.

TABLE CCCLXXXIV. ESTIMATED ANNUAL INCREASE IN ACCOUNT No. 6—ROADWAY AND TRACK, 600-VOLT D. C. OPERATION ON THE CHICAGO & NORTH WESTERN RAILWAY

(Basis of 1912)

Miles of Track	Steam Operation		Estimated Annual Cost of Labor with 600-Volt D. C. Installation		Increase Due to 600-Volt D. C. Installation	
	Per Mile	Total	Per Mile	Total	Per Mile	Total
1	2	3	4	5	6	7
532	$70.85	$37,691	$81,477	$43,346	$10,627	$5,655

The total expense chargeable to Account No. 6 for all roads for the year 1912 amounted to $243,663. This expense is apportioned to the different services as follows:

Through passenger	$ 54,142
Suburban passenger	42,617
Road freight	19,688
Yard and transfer	127,216
Total	$243,663

Account No. 7—Removal of Sand, Snow and Ice: The installation and operation of either the 2,400-volt direct current or the 11,000-volt alternating current system of traction will involve no change in the expenditures chargeable to this account. The installation and operation of the 600-volt direct current third rail system, however, will involve an increase due to the necessity of removing sleet or snow from the third rail and also to the fact that the space alongside the tracks available for piling snow is restricted by the presence of the third rail. These conditions will effect an increase in the expense of clearing tracks at stations, switches and crossovers, and in yards where the track arrangement is complex and the activities are constant. In estimating the increase in expense under this account, the Committee has studied the operation of electrified steam roads in other parts of the country and has made due allowance for differences in climatic conditions so as to reduce known or established values to the basis of Chicago's conditions

The removal of snow and ice under third rail operation is accomplished by means of special equipment. The expense of operating this equipment has been estimated on the basis of facts obtained from roads operating the third rail system. The Long Island Railroad, which operates electrically about 200 miles of track, employs two calcium chlorid cars which are sent over the lines during or following a storm. In addition, patrol trains are employed on exposed parts of the lines during periods of storm. Three of these patrol trains are used on the Long Island Railroad. They are equipped with sleet cutting shoes which serve to remove the ice or sleet from the third rail after the application of calcium chlorid. The expense of operating these calcium chlorid and patrol trains amounts to about $30.00 per day per train.

The meteorological records for New York show that during the past seven or eight years there have been, on the average, six storms annually, the severity of which would require the use of the special equipment provided. The average period of duration of storms has been about one day each. On the basis of this record, the additional cost per annum of removing snow and ice on the Long Island Railroad may be analyzed as follows:

One day for each of 4 trains, at $30.00 per day	$120.00
One man for each 10 miles of track for one day, at $2.25 per day	45.00
Total for each storm	$165.00
Total per annum for 6 storms	$990.00
Average additional expense per mile of track per annum	$4.95

It is reported that the average additional expense chargeable to this account on the Pennsylvania Railroad's New York terminal electric traction system is $5.70, and on the West Jersey and Seashore's electric lines $4.53, per mile of track per annum.

For the purposes of these estimates, the additional expense which will be involved in the removal of snow and ice under third rail operation of the Chicago terminals has been fixed at $5.00 per mile of track per annum.

The expenditure for the removal of snow, sand and ice from the tracks of the Chicago & North Western Railway within the proposed limits of electrification, during the year 1912, amounted to $84,186. The estimated additional cost of $5.00 per mile of track is therefore equivalent to an increase of 3.16 per cent.

The application of this estimated unit increase to all the trackage of the Chicago & North Western Railway embraced by the plan of electrification yields results as shown by table CCCLXXXV.

TABLE CCCLXXXV. ESTIMATED ANNUAL INCREASE IN ACCOUNT No. 7—REMOVAL OF SAND, SNOW AND ICE 600-VOLT D. C. OPERATION ON THE CHICAGO & NORTH WESTERN RAILWAY

(Basis of 1912)

Miles of Track	Cost of Removal of Sand, Snow and Ice, with Steam Operation	Estimated Annual Cost of Removal of Sand, Snow and Ice with 600-Volt D. C. Installation	Increase Due to 600-Volt D. C. Installation	
			Per Mile	Total
1	2	3	4	5
532	$84,186	$86,846	$5.00	$2,660

In determining the additional expense chargeable to this account, no consideration has been given to the added cost of increased delays in train movements due to the difficulties of removing snow and ice promptly under all conditions. It is believed, however, that the special equipment for removal of snow and ice, provided for in the Committee's estimates (section 213.128), will prove adequate for the prompt handling of any situation which may ordinarily arise.

The total cost to all roads due to expenditures chargeable to Account No. 7 during the year 1912 was $240,740. This expense has been apportioned to the different services as follows:

Through passenger	$ 53,492
Suburban passenger	42,105
Road freight	19,452
Yard and transfer	125,691
Total	$240,740

Account No. 8—Tunnels: There are no tunnels within the proposed limits of electrification and consequently no expense chargeable to this account. No change will result from the installation and operation of any of the proposed electric traction systems.

Account No. 9—Bridges, Trestles and Culverts: The installation and operation of any of the electric systems proposed will involve a slight increase in the expense of cleaning and painting bridges to which transmission or contact wires may be attached, but the amount has been regarded as slight and no estimates to cover it have been made.

Account No. 10—Over and Under Grade Crossings: As in the case of Account No. 9, the presence of transmission lines or of other wire lines incident to electric installations will involve a slight increase in the cost of cleaning and painting structures employed for over or under grade crossings, but no quantitative estimates to cover this increase have been made.

Account No. 11—Grade Crossings, Fences, Cattle-Guards and Signs: The installation and operation of either the 2,400-volt direct current or the 11,000-volt alternating current system of traction will involve no change in the expenditures chargeable to this account. The operation of the 600-volt direct current third rail system will, however, require the installation and maintenance of additional wing and right-of-way fences and cattle-guards, the presence of which is required in the interest of safe operation. The estimated expense of maintaining bridge and contact wire warnings for the 2,400-volt and the 11,000-volt systems is considered hereinafter in the analysis of Account No. 15.

It has been estimated (section 213.123) that the installation cost of the additional fences and cattle-guards required on a single road, the Chicago & North Western Railway, on the basis of 1912, will be $30,040. The annual maintenance expense of such structures, not including depreciation, has been estimated at 10 per cent of the installation cost. The added maintenance expense to this road under this account will therefore be $3,004. The amount charged to this account by the Chicago & North Western Railway during the year 1912 was $2,277.62 and the expense under third rail operation will be $5,281.62. This increase has been considered in determining the expense of the third rail operation of all roads within the proposed limits of electrification, by extending this unit to cover all roads in the manner hereinbefore described (section 301.04).

The total expenditures of all roads chargeable to Account No. 11 during the year 1912 amounted to $42,608. This expense is apportioned to the different services, as follows:

Through passenger	$ 9,467
Suburban passenger	7,452
Road freight	3,443
Yard and transfer	22,246
Total	$42,608

Account No. 12—Snow and Sand Fences and Snow Sheds: No structures of this character exist within the proposed limits of electrification and none will be required as a result of the electric installation. There are, therefore, no expenditures chargeable to this account for steam operation and there will be none for electric operation.

Account No. 13—Signals and Interlocking Plants: In the proposed change from steam to electric operation, no changes are contemplated in the number or type of existing signals. The introduction of any of the systems of electric traction proposed will, however, involve additions to present signal control apparatus or, in some cases, the substitution of new apparatus. It will also involve a new power supply with its transmission lines. These additions and changes will effect an increase in the present operating expense chargeable to this account.

Data are not available upon the basis of which determination may be made of the final net effect of these changes in apparatus upon the operating and maintenance expense of the signal installations within the proposed limits of electrification. From present knowledge and information, however, the effects of the changes may be analyzed.

The maintenance of track circuits will not be affected by the character of current flowing in them, but the maintenance of certain portions of the controlling apparatus connected with the track circuits will be subject to change, owing to the requirement of additional apparatus for the alternating current circuits, which apparatus is not needed in the circuits using direct current. The omission of the track circuit battery sets will also have some effect. The principal elements which are required to make up the track circuits under electric operation are:

1. Track wiring.
2. Relays.
3. Impedance bonds.
4. Track transformers.

The first two of these elements constitute necessary parts of the track circuit under steam operation. The impedance bonds and the track transformers are additional apparatus required under electric operation. Both of these pieces of apparatus are durable and require only occasional inspection, repairs and renewals. The additional maintenance expense for the added track circuit apparatus has been estimated as follows:

	PER CIRCUIT MILE PER ANNUM
600-volt and 2,400-volt direct current systems	$12.00
11,000-volt alternating current system	9.00

With reference to the relays it may be assumed without material error that any change from alternating current to direct current relays will not involve a change in the maintenance expense. The maintenance expense of the track circuit battery sets which will be displaced as a result of the installation of an electric traction system is about $1.00 per month per circuit or $12.00 per annum. This amount may be regarded as a credit in considering the effect of the change from steam to electric operation upon the expenditures chargeable to this account. The addition of the maintenance expense of the new track circuits will, therefore, in the case of the direct current system of traction, be offset by this reduction due to electrification, and no change in the operating expense of the track circuit apparatus proper will result. In the case of the alternating current system of traction, the credit of $12.00 per annum due to the elimination of the track battery sets will more than offset the new charge of $9.00 per circuit mile per annum due to maintenance of added track circuit apparatus, leaving a credit as a result of electrification of $3.00 per circuit mile per annum.

The introduction of the transmission systems for the track circuit current will involve an added maintenance expense, which may be assumed to be equal to that involved in the maintenance of the high tension transmission power line. Upon this basis the annual maintenance expense for the transmission system for the track circuit current will be:

	PER MILE
For the 600-volt direct current third rail system . .	$40.00
For the 2,400-volt direct current or the 11,000-volt alternating current system	25.00

The difference between the maintenance expense under the third rail system and that under the two overhead systems is due to the necessity of including, in the case of the third rail system, the expense of maintaining a pole line which, with the other two systems, is supplied by the supporting structures for the overhead contact.

Under present steam operation the track circuit control and the automatic signal movements proceed from a primary battery power supply. Under the proposed electric operation batteries will continue to be used for operating the signals, but the track circuit batteries will be displaced by the centralized alternating current power supply from the central power station provided for traction purposes. Thus, the expense of inspecting and cleaning batteries for operating the signals will not be changed and the expense of the alternating current power plant operation and maintenance will be added. Alternating current power from a steam power plant is much cheaper than direct current power produced by chemicals in a primary battery. For this reason a net saving in the cost of power would result from the proposed change, were it not for the fact that alternating current track circuits require more energy than do direct current circuits. The maintenance and operating expense of the signal power substations is dependent largely upon the local conditions to be met in each installation. In cases in which the signal power substations may be located in buildings provided for traction power substations, or in or near other buildings where attendance is provided for other purposes, the added operating expense will not be great; but where separate plants are required for the signal power substations the increase resulting will be appreciable. A detailed study has been made of local conditions in the Chicago terminals with reference to this subject, and it is estimated that the expense of operation and maintenance of the signal power substations within the proposed limits of electrification will amount annually to seven per cent of the installation cost.

For the 2,400-volt direct current or the 11,000-volt alternating current system, a total of 17 signal power substations will be required within the proposed limits of electrification. Three of these substations will cost $11,000 each and 14 will cost $15,000 each, the average unit cost being $14,294. On the basis of an annual maintenance expense equivalent to seven per cent of the first cost, the average annual expense per substation will be $1,000.

The application of the unit values resulting from the foregoing analysis, to the total quantities involved in the signal system proposed under electric operation, yields additional expenses for the maintenance and operation of the signal installation under the 2,400-volt direct current system and the 11,000-volt alternating current systems, as shown by table CCCLXXXVI.

TABLE CCCLXXXVI. ESTIMATED INCREASE IN ACCOUNT No. 13—SIGNALS AND INTERLOCKING PLANTS ELECTRIC OPERATION OF ALL ROADS

(Basis of 1912)

Item		2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Transmission lines and track circuits	343.1 miles	$ 8,578	$ 7,548
Signal power substations	17	17,000	17,000
Totals	... .	$25,578	$24,548

Reports furnished by the railroads indicate that the expense of operating and maintaining the signal systems of all roads, within the proposed limits of electrification, during the year 1912, amounted to $405,512. By adding to this amount the estimated increases incident to electric operation and apportioning the totals among the four services recognized, results are obtained for 2,400-volt direct current operation and for 11,000-volt alternating current operation as shown by table CCCLXXXVII.

TABLE CCCLXXXVII. ESTIMATED TOTAL EXPENSE UNDER ACCOUNT No. 13—SIGNALS AND INTERLOCKING PLANTS ELECTRIC OPERATION OF ALL ROADS

(Basis of 1912)

Service	Steam 1912	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Through passenger..............	$ 90,105	$ 95,788	$ 95,559
Suburban passenger..............	70,924	75,398	75,217
Road freight	32,765	34,832	34,749
Yard and transfer	211,718	225,072	224,535
Totals	$405,512	$431,090	$430,060

The estimated unit increase under this account for the 600-volt direct current third rail system has been applied to the Chicago & North Western Railway and has been used in determining the ratio of the expense of third rail operation to that of steam operation, in the manner described, with results as shown by table CCCLXXXVIII.

TABLE CCCLXXXVIII. ESTIMATED INCREASE IN ACCOUNT No. 13—SIGNALS AND INTERLOCKING PLANTS ELECTRIC OPERATION OF THE CHICAGO & NORTH WESTERN RAILWAY

(Basis of 1912)

Item		600-Volt D. C.
1	2	3
Transmission lines and track circuits........	84.1 miles	$3,364
Signal power substations..................	2	2,000
Total..............................	....	$5,364

The report furnished by this road shows that the expense of operating and maintaining its signal system, within the proposed limits of electrification, during the year 1912, amounted to $117,651. By adding to this amount the estimated increase incident to electric operation, the cost of operation of signals and interlocking plants totals $123,015.

Account No. 14—Telegraph and Telephone Lines: The installation and operation of any of the proposed electric traction systems will involve the installation and the maintenance of additional telephone facilities to provide a patrol line by means of which prompt communication may be established at any time between fixed points along the line of road, and the power station and operating headquarters.

The patrol line will consist of an overhead open wire circuit installed along all main track right-of-way and connected to serve telephone instruments placed in protecting boxes at half-mile intervals. The estimates provide for the rental of telephone instruments. The annual maintenance expense of the patrol line is estimated at $6.00 per mile and that of the protecting boxes at $1.00 each or $2.00 per route mile, the total annual maintenance expense being $8.00 per mile of patrol line. Since the estimates provide for the installation of the patrol line along all main track right-of-way, the number of miles of patrol line is equivalent to the number of miles of main line route. On the basis of 1912, there are 565.5 route miles within the limits of electrification and the total annual maintenance expense of patrol lines to all roads will therefore be $4,524. The amount will be the same for each of the electric traction systems proposed. The rental charges and the operating expense of the telephone instruments are hereinafter considered (Account No. 94). The maintenance of the apparatus required for the prevention of inductive effects in the case of the proposed 11,000-volt alternating current system of traction is considered under Account No. 15. The expense of operating and maintaining telegraph and telephone lines during the year 1912, as indicated by reports furnished by the railroads, amounted to $39,864. By adding to this amount the estimated maintenance expense of the patrol line required under electric operation and by apportioning the totals to the four services recognized, results are obtained as shown in table CCCLXXXIX.

TABLE CCCLXXXIX. ESTIMATED ANNUAL EXPENSE UNDER ACCOUNT No. 14—TELEGRAPH AND TELEPHONE LINES STEAM AND ELECTRIC OPERATION OF ALL ROADS

(Basis of 1912)

Service	Steam 1912	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Through passenger..............	$ 8,859	$ 9,863	$ 9,863
Suburban passenger	6,971	7,762	7,762
Road freight...	3,222	3,588	3,588
Yard and transfer	20,812	23,171	23,171
Totals	$39,864	$44,384	$44,384

The estimated unit increase under this account for the 600-volt direct current system is the same as for the 2,400-volt direct current and the 11,000-volt alternating current systems. This unit has been applied to the route mileage of the Chicago & North Western Railway and the result used in determining the increased expense of third rail operation on this road in the manner described. The additional cost, under conditions existing in 1912, amounts to $736. The expense of maintenance as reported by the railroad amounted, in 1912, to $2,634. The estimated total expense under third rail operation is, therefore, $3,370.

Account No. 15—Electric Power Transmission: The estimated operating expense chargeable to this account under any of the proposed systems of electric traction will constitute additions to the present operating expense, there being no charges to this account under steam operation.

The estimated expense chargeable to this account includes the expense of maintenance and inspection of all parts of the electric traction system between the power station and the collecting devices of the locomotives and motor cars, except the expense of maintaining substations, which is hereinafter considered under Account No. 47. The items to be considered under this account, therefore, include the following:

1. The maintenance and inspection of high tension transmission lines; also the maintenance and inspection of supporting structures and foundations for the transmission lines; or, in instances in which the same structures are used for supporting both the transmission lines and the overhead contact construction, that portion of the expense of maintenance and inspection of such structures which is chargeable to transmission. (The maintenance of high voltage feeder circuits used in connection with the signal system is not considered under this account even though conductors for such circuits may be mounted on the same structures with the transmission lines.)

2. The maintenance and inspection of contact systems with distributing feeders, if any (overhead catenary construction or third rail), including the maintenance of supporting structures and foundations, or of such portions of this as may be chargeable to contact systems. In the case of the 11,000-volt alternating current system of traction, this item includes the maintenance of transformers to be provided for the prevention of inductive effects in telegraph and telephone circuits. In the case of the third rail system of traction, this item includes the expense of maintenance of cables and cross connections, of protection boards and of overhead third rail sections with supporting structures, where used.

3. The expense of maintaining the bonding of track rails, cross-bonding between tracks and substation connections. (The expense of maintenance and operation of substations, including buildings, though properly a part of the operating expense of the transmission and distribution systems, is considered under Account No. 47.)

Information was obtained from the railroads operating electric traction systems, covering the actual expense of maintenance and inspection of high tension transmission lines as indicated by their records, and these values were accepted as a basis upon which to estimate this expense for the systems of electric traction proposed for the Chicago terminals. Wherever possible, the average figures for a period of years were obtained. These values are shown by table CCCXC.

The reported expense of maintenance and inspection of the high tension transmission line of the West Jersey & Seashore Railroad is very low in comparison with expenses reported by other roads. This is probably due to the type of construction employed and to the difference in operating conditions on this road and on the other roads to which reference has been made. It is to be noted, however, that conditions on the West Jersey & Seashore Railroad are not in any respect similar to those which must be met under the proposed electric operation of the Chicago terminals.

TABLE CCCXC. ANNUAL EXPENSE OF MAINTENANCE AND INSPECTION OF HIGH TENSION TRANSMISSION LINES, AS REPORTED BY RAILROADS OPERATING ELECTRIC TRACTION SYSTEMS

Railroad	System	Average Period, Years	Cost per Mile of Wire per Annum
1	2	3	4
Long Island Railroad	11,000-volt three-phase line supported on steel poles	6	$59.00
Pennsylvania Terminal, New York	11,000-volt three-phase line supported on steel poles	3	41.00
West Jersey & Seashore Railroad . .	33,000-volt three-phase line supported on wooden poles	5	12.00
Norfolk & Western Railroad . . .	44,000-volt single-phase line supported on catenary bridges . .		25.00*

* Estimated

In some instances the transmission lines are maintained by a separate organization. In other instances, the same force is used for the maintenance and inspection of both the transmission lines and the contact system. It is contemplated that the latter method will be employed under the electric operation of the Chicago terminals. On the Pennsylvania Terminal in New York City the same force is used for the maintenance and inspection of both the transmission line and the third rail contact system, and for the purpose of these estimates the average annual expense reported for this electrification, or about $40.00 per wire mile per annum for the transmission line, is regarded as applicable to the Chicago terminals. For transmission lines mounted on catenary bridges, the estimated annual expense of maintenance and inspection has been fixed at $25.00 per wire mile per annum, in accordance with the estimated expense for this item on the Norfolk & Western Railway.

In estimating the expense of maintenance and inspection of the contact system, consideration has been given to the reported expense for such items on railroads now operating electric traction systems. In this study two types of contact systems have been considered, third rail construction and overhead catenary construction.

The average annual expense of maintenance and inspection of third rail contact systems, as indicated by the records of railroads now operating such systems of traction, is shown by table CCCXCI.

TABLE CCCXCI. ANNUAL EXPENSE OF MAINTENANCE AND INSPECTION OF THIRD RAIL CONTACT SYSTEM, AS REPORTED BY RAILROADS OPERATING ELECTRIC TRACTION SYSTEMS

Railroad	Average Period Years	Expense per Mile of Track per Annum
1	2	3
Long Island Railroad	6	$210 00
Pennsylvania Terminal, New York	3	300 00
West Jersey & Seashore Railroad	5	110.00

The reported expense of this item on the West Jersey & Seashore Railroad is lower than the amounts indicated by the records of the other two roads. This condition is due to the fact that labor costs are lower on the West Jersey & Seashore Railroad than on the other two roads, and also to the fact that the third rail of the West Jersey & Seashore Railroad was not fitted with protection boards until several years after the installation.

For the purposes of these estimates, it was thought desirable to separate the expense of maintaining main line third rail construction from that of maintaining yard track third rail construction. The figures reported for the Long Island Railroad, which has very little yard track, and the figures reported for the Pennsylvania Terminal, which consists largely of yards and tunnels, have been accepted as a basis for the estimated expense of maintenance and inspection of third rail construction on the Chicago terminals. Owing, however, to the fact that the track arrangement in Chicago is, on the average, more complex than that on either of the roads mentioned, and also to the fact that the physical difficulties to be met in Chicago are more pronounced, it has been estimated that the expense for this item under Chicago conditions will be approximately 10 per cent greater than the amounts reported for the Long Island Railroad and the Pennsylvania Terminal. Thus, the estimated average annual expense of maintenance and inspection of main line third rail construction in Chicago has been fixed at $230 per mile of track and that of yard track third rail construction at $340 per mile of track.

Reliable data relating to the actual expense of the maintenance and inspection of overhead catenary contact systems have not been available owing to the fact that there are few railroads which have operated an overhead catenary contact system of electric traction for a sufficient period to provide records of maintenance expense not complicated by the costs of new construction or by the expense of changes made in the progress of construction. Reports covering the maintenance expense of the overhead contact system of the New York, Westchester & Boston Railroad during the year 1913, including the expense of maintenance of track bonding, indicate the average expense to be $228 per mile of track.

By carefully estimating the labor required for the maintenance and inspection of an overhead catenary contact system and by adding to this amount the estimated cost of materials required, an annual expense of $240 per mile of track is obtained. This estimate includes the cost of painting supporting structures for the contact system. It will be noted that this estimated expense is in fairly close agreement with the reported expense of this item on the New York, Westchester & Boston Railroad. For purposes of these estimates, this unit expense of $240 per track mile per annum is regarded as applicable to both the 2,400-volt direct current and the 11,000-volt alternating current systems of traction, as proposed for the Chicago terminals. This amount is regarded as sufficient to cover expense of maintenance of any supplementary feeders and connections which may be used with the 2,400-volt system, and also the expense of the maintenance of booster transformers and connections required for the 11,000-volt alternating current system. In both cases the amount is accepted as the average to be applied to both main and yard track.

The reported expense of maintaining track bonding on existing electric traction systems elsewhere is shown, for different roads, by table CCCXCII.

TABLE CCCXCII. ANNUAL EXPENSE OF MAINTAINING TRACK BONDING ON THIRD RAIL CONTACT SYSTEM, AS REPORTED BY RAILROADS OPERATING ELECTRIC TRACTION SYSTEMS

Railroad	Expense per Mile of Track per Annum
Long Island Railroad	$81.00
Pennsylvania Terminal, New York	38.00
West Jersey & Seashore Railroad	20.00

It will be noted that the reported expense of maintaining track bonding on the Long Island

Railroad is higher than that reported for either of the other two roads mentioned. This is the result partly of track conditions and partly of the presence in the track of many bonds of old types, the maintenance expense of which is high. The expense reported for the maintenance of track bonding on the Pennsylvania Terminal represents the average for a three-year period. It is significant, however, that the expense during the last year of this period is approximately double the average of the first two years.

Based upon a study of these reported expenses of the maintenance of track bonding on electric traction systems elsewhere, it has been estimated that the average annual expense of maintaining track bonding on the Chicago terminals will be $40.00 per track mile for the alternating current system and $45.00 per track mile for either of the direct current systems, the difference being due to a difference in the cost of bonds.

By applying the estimated unit expenses, determined as set forth in the preceding paragraphs, to the establishment involved in the proposed electrification of Chicago's railroad terminals, values are obtained for the total annual expense of electric power transmission for both the 2,400-volt direct current and the 11,000-volt alternating current systems of traction as shown by table CCCXCIII.

TABLE CCCXCIII. ESTIMATED TOTAL EXPENSE OF ELECTRIC POWER TRANSMISSION—ALL ROADS
(Basis of 1912)

Item	2,400-Volt D. C.			11,000-Volt A. C.		
	Miles	Annual Expense per Mile	Total Annual Expense	Miles	Annual Expense per Mile	Total Annual Expense
1	2	3	4	5	6	7
1. High tension transmission	678.00	$ 25.00	$ 16,950	950.00	$ 25.00	$ 23,750
2. Contact system:						
Main track	1,475.59	240.00	354,142	1,475.59	240.00	354,142
All other track	1,963.55	240.00	471,252	1,963.55	240.00	471,252
3. Track bonding	3,456.34	45.00	155,535	3,439.14	40.00	137,566
Totals			$997,879			$986,710

These costs are distributed by services as shown in table CCCXCIV.

TABLE CCCXCIV. ESTIMATED TOTAL EXPENSE OF ELECTRIC POWER TRANSMISSION, BY SERVICES
(Basis of 1912)

Service	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3
Through passenger	$221,729	$219,247
Suburban passenger	174,529	172,576
Road freight	80,629	79,726
Yard and transfer	520,992	515,161
Totals	$997,879	$986,710

The estimated unit expense of electric power transmission under the 600-volt direct current third rail system of traction has been applied to the proposed electric installation on the Chicago & North Western Railway with results which are presented in table CCCXCV.

TABLE CCCXCV. ESTIMATED TOTAL ANNUAL EXPENSE OF ELECTRIC POWER TRANSMISSION, CHICAGO & NORTH WESTERN RAILWAY
(Basis of 1912)

Item	600-Volt D. C.		
	Miles	Annual Expense per Mile	Total Annual Expense
1	2	3	4
High tension transmission	444.00	$ 40.00	$17,760
Contact system:			
Main track	263.46	230.00	60,596
All other track	268.54	340.00	91,304
Track bonding	532.00	45.00	23,940
Total			$193,600

The results presented for the Chicago & North Western Railway have been extended to cover the proposed 600-volt direct current third rail installation for all roads in a manner which has already been described (section 301.04).

*Account No. 16—Maintenance of Buildings, Fixtures and Grounds:** The installation of any of the proposed systems of electric traction will involve the construction of many new buildings, such as houses for electric locomotives and motor cars, repair shops, locomotive roundhouses, water tanks, cinder-pits and other structures which will be required for the accommodation of both steam and electric equipment under the new operating conditions. It will also involve the abandonment and removal of many of the present facilities for the care of steam locomotives within the proposed limits of electrification.

Subsequent to electrification the railroads will be relieved of the expense of maintaining structures and facilities to be abandoned and they

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* Not including power house and substation buildings, the maintenance of which is considered under Accounts 47-B and 86.

will assume the expense of maintaining the new facilities to be provided.

Reports furnished by the railroads, covering operation of the Chicago terminals for the year 1912, indicate that the total amount expended for maintenance of those structures and fixtures which are to be abandoned was $333,596, and that the value of such structures and fixtures at the end of the year 1912 was $2,318,604. On the basis of these values the average expense for the maintenance of buildings, fixtures and grounds during 1912 was $97.00 per track mile and the total annual expense for this item was about 14 per cent of the estimated value of the structures involved. Included in the amount reported for maintenance expense, however, were some charges which represented renewals and which are not properly to be considered as a maintenance expense. A careful study of the expenditures reported for 1912 indicates that 6 per cent of the estimated value is sufficient to cover the annual expense of maintaining buildings and fixtures in proper repair. On the basis of the estimated value of $2,318,604 for buildings and fixtures in 1912, the estimated annual maintenance expense would be $139,116, or $40.45 per track mile.

It is estimated that the total value of all new structures and fixtures, exclusive of land, tracks and track fixtures incident to the electric installation, will be $10,710,381.* Upon the basis of an estimated annual maintenance expense of 6 per cent for buildings, fixtures and grounds, the total expense for such maintenance after electrification will be $642,623. The estimated total expenditures under this account, apportioned to the four classes of service on a locomotive-mileage basis for steam operation, for 2,400-volt direct current operation and for 11,000-volt alternating current operation, are shown by table CCCXCVI.

The estimated expense for maintenance of buildings, fixtures and grounds on the Chicago & North Western Railway for steam operation in 1912 amounted to $22,056 on a present value of $367,600 for buildings, fixtures and grounds to be abandoned. Electric operation with the 600-volt direct current system under conditions existing in 1912 will involve new facilities, subject to maintenance under this account, to the value of $2,145,325. The annual expense under this account, subsequent to electrification, will, therefore, amount to $128,720. These results have been extended to cover the proposed third rail installation on all roads in the manner hereinbefore described (section 301.04).

TABLE CCCXCVI. ESTIMATED TOTAL ANNUAL EXPENSE UNDER ACCOUNT No. 16—MAINTENANCE OF BUILDINGS, FIXTURES AND GROUNDS. STEAM AND ELECTRIC OPERATION (Basis of 1912)

Service	Steam 1912	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Through passenger	$ 30,912	$142,791	$142,791
Suburban passenger	24,331	112,395	112,395
Road freight	11,240	51,924	51,924
Yard and transfer	72,633	335,513	335,513
Totals	$139,116	$642,623	$642,623

Account No. 17—Docks and Wharves: The installation and operation of any of the electric traction systems proposed by the Committee will involve no change in the expenditures chargeable to this account.

Account No. 18—Roadway Tools and Supplies: Included under this account are the expenses of providing tools and supplies for roadway and track, such as axes, bars, chains, track chisels, hammers, lanterns, rail benders, rail tongs, shovels, tool-boxes, wheelbarrows, fuel for portable forges, gasoline for motor cars, torpedoes used by track walkers, and numerous other items. The installation and operation of any of the proposed electric traction systems will involve a slight increase in the expenditures under this primary account, due to the necessity of providing certain special tools for the maintenance of electric traction systems which are not needed for the maintenance of steam traction systems. The amount of this increase is, for the purpose of these estimates, regarded as indeterminate.

Account No. 19—Injuries to Persons: The expenditures chargeable to this account include those resulting from injuries to persons which occur directly in connection with maintenance of way and structures, injuries occurring in connection with the operation of work trains in such service, and injuries caused by defective highways within the right-of-way. The proposed change from steam to electric operation will involve no measurable or determinate change in the expenditures under this account. The general

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*This item does not include power house and substation buildings.

subject of injuries to persons is considered elsewhere in this report (chapter 303).

Account No. 20—Stationery and Printing: The installation and operation of any of the proposed electric traction systems will involve no change in the expenditures chargeable to this account.

Account No. 21—Other Expenses: The installation and operation of any of the proposed electric traction systems will involve no change in the expenditures chargeable to this account.

Account No. 22—Maintenance of Joint Tracks, Yards and Other Facilities, Dr.: The installation and operation of any of the proposed electric traction systems will involve no change in the charges to this account.

Account No. 23—Maintenance of Joint Tracks, Yards and Other Facilities, Cr.: The installation and operation of any of the electric traction systems proposed will involve no change in the charges to this account.

2. *Maintenance of Equipment*

Account No. 24—Superintendence: Included under this account are the expenses involved in the pay of officers, clerks and other employes in charge of, or engaged in, the maintenance of equipment, and the office expenses and other expenses of such officers and employes. The installation and operation of any of the proposed systems of electric traction will involve no change in the expenditures chargeable to this account. The expense of new officers and employes, if any, who will be required after electrification will, it is estimated, be offset by the saving which may be gained by the elimination of certain officers and employes who will not be required after electrification.

Account No. 25—Steam Locomotives, Repairs. Account No. 28—Electric Locomotives, Repairs: The proposed change from steam to electric operation will involve the elimination of steam locomotives from the trackage within certain defined limits (chapter 209) and the substitution therefor of electric locomotives. The present expense of repairs and maintenance of steam locomotives within these limits will be eliminated and that of repairing and maintaining electric locomotives will be introduced. It is estimated that the expenses chargeable to this account under electric operation will be less than those chargeable to it under steam operation.

The cost per locomotive-mile of repairs to steam locomotives was determined from reports furnished by the railroads operating in the Committee's Area of Investigation, the average for a period of five years, 1908 to 1912, inclusive, for each of the 25 roads reporting, being used in these determinations. The reports were compiled to set forth the cost per locomotive-mile of steam locomotive repairs for each year of this period and for each of the services recognized. The records of some of the roads did not permit a segregation of expenses to each of the different services, but such roads were able to supply figures for through passenger, road freight and yard services, there being no separate figures for suburban passenger service. In instances where only one rate per locomotive-mile was given for passenger locomotives, that rate was applied to both through and suburban passenger locomotives. The total annual expenditure for each road under this primary account was determined by applying the average expense per locomotive-mile, as given by each road, to the number of locomotive-miles made in each service. The average expenditure per locomotive-mile for the five-year period for the 25 roads which reported, was applied to the locomotive-mileage performed in 1912 by all roads within the proposed limits of electrification, and the estimated total expense for repairs to steam locomotives on this basis was shown to be $1,746,395.

Information relating to the expense of repairing and maintaining electric locomotives is, at this time, not of a very satisfactory character. The number of electric locomotives in use and the length of the service up to the present time have been limited. In many cases the cost of correcting defective designs or of making fundamental changes in the mechanism has been included in the expense of repairs and maintenance. The only accessible figures possessing any degree of accuracy or completeness are those which relate to direct current locomotives; figures for repairs to single-phase alternating current locomotives are entirely lacking.

Based upon all available information, however, the Committee's consulting electrical engineers have made a careful study of the question of expense of repairs to electric locomotives, and for the purpose of these estimates unit figures have been fixed as follows:

	PER LOCOMOTIVE-MILE
For 2,400-volt d. c. or 11,000-volt a. c. passenger locomotives	$0.055
For 600-volt d. c. passenger locomotives	0.050
For 2,400-volt d. c. or 11,000-volt a. c. freight locomotives	0.055
For 600-volt d. c. freight locomotives	0.050
For 2,400-volt d. c. or 11,000-volt a. c. yard and transfer locomotives	0.050
For 600-volt d. c. yard and transfer locomotives	0.050

The application of these units of expense to the locomotive-mileage performed in 1912 on the trackage to be electrified yields results as shown by table CCCXCVII.

TABLE CCCXCVII. ESTIMATED EXPENSE OF REPAIRS AND MAINTENANCE OF STEAM AND OF ELECTRIC LOCOMOTIVES — ALL ROADS
(Basis of 1912)

Service	Steam			2,400-Volt D. C. and 11,000-Volt A. C.		
	Loco.-Miles per Annum	Average per Locomotive-Mile	Total per Annum	Loco.-Miles per Annum	Average per Locomotive-Mile	Total per Annum
1	2	3	4	5	6	7
Through passenger	5,387,035	$0.06525	$ 351,504	5,387,035	$0.05500	$ 296,287
Suburban passenger	4,239,110	0.08899	377,238	None	....	....
Road freight	1,959,685	0.08170	160,106	1,959,685	0.05500	107,783
Yard, including transfer	12,655,645	0.06776	857,547	12,655,645	0.05000	632,782
All services	24,241,475	$0.07204	$1,746,395	20,002,365	$0.05184	$1,036,852

The estimated expense of locomotive repairs and maintenance on the Chicago & North Western Railway for steam operation and for 600-volt direct current third rail operation is shown by table CCCXCVIII.

TABLE CCCXCVIII. ESTIMATED EXPENSE OF REPAIRS AND MAINTENANCE OF STEAM AND OF ELECTRIC LOCOMOTIVES ON THE CHICAGO & NORTH WESTERN RAILWAY
(Basis of 1912)

Service	Steam			600-Volt Direct Current		
	Loco.-Miles per Annum	Average per Mile	Total per Annum	Loco.-Miles per Annum	Average per Mile	Total per Annum
1	2	3	4	5	6	7
All services	4,481,809	$0.06886	$308,615	3,263,439	$0.05000	$163,172

It will be noted that no estimates are here presented, to cover the expense of maintaining and repairing electric motive power equipment for suburban passenger service. This service will be performed by multiple-unit trains, the expense of repairs to which is considered in the analysis of Account No. 31.

Account No. 26—Steam Locomotives, Renewals. Account No. 29—Electric Locomotives, Renewals: For the purposes of these estimates, no consideration has been given to the expenditures chargeable to these accounts.

Account No. 27—Steam Locomotives, Depreciation. Account No. 30—Electric Locomotives, Depreciation: The subject of depreciation has not been considered in these estimates. The effect of electrification upon charges to depreciation accounts is elsewhere considered (chapter 401).

Account No. 31-A—Multiple-Unit Trailer Cars, Repairs. Account No. 31-B—Multiple-Unit Motor Cars, Repairs. Account No. 37—Electric Equipment of Multiple-Unit Motor Cars, Repairs: The proposed change from steam to electric operation will involve the substitution, in practically all of the suburban passenger service within the proposed limits of electrification, of multiple-unit trains for trains now hauled by locomotives. These multiple-unit trains will consist of motor and trailer cars, the motor cars being equipped with motors and driving mechanism for the propulsion of the trains. In the analysis of the three accounts under consideration, attention is to be given to the expense of maintaining the cars used in suburban passenger service both under steam operation and under the proposed electric operation. The expense of repairs to steam locomotives now used in this service is considered in the analysis of Accounts Nos. 25 and 28.

The expense of repairs to passenger coaches now used in suburban service was determined from reports furnished by the railroads. These reports, in most cases, cover the expenditures under this account for a period of five years, 1908 to 1912, inclusive. In some instances the records of the railroads did not permit a segregation of the expense of repairs to suburban passenger coaches and of that of repairs to all other passenger coaches. In such instances, the unit determined for all passenger cars on the road in question was accepted as the basis of these estimates. The average unit expense of repairs to suburban cars, as indicated by the reports of the railroads, was 1.107 cents per car-mile. This unit has been applied to the total suburban passenger car-mileage performed by all railroads within the proposed limits of electrification during the year 1912 to obtain the total expense of repairs to suburban passenger cars under steam operation.

Under electric operation, according to the plan of the Committee, all cars for the multiple-unit trains will be of modern steel construction. These will replace the existing wooden cars, which are of various designs and many of which are not in first-class condition. For purposes of these estimates it is assumed that the expense of maintaining steel trailer cars to be used in multiple-unit passenger service will be the same as the present cost of maintaining passenger cars now used in suburban service, or 1.107 cents per car-mile.

The multiple-unit motor cars, while of the same general design as the multiple-unit trailer cars, will be equipped with heavier trucks, with more complicated brake equipment and with more elaborate electric apparatus. Because of these factors the expense of maintaining motor cars will be greater than that of maintaining trailer cars. The estimated net effect of these factors upon the expense of repairs is considered in the following paragraphs.

Some of the trucks of motor cars are equipped with motors and driving mechanism. These are heavier than the trailing trucks and are equipped with larger wheels and larger bearings. The motor trucks, in service, are subjected to greater stresses than the trailing trucks, owing to the presence of the motors and driving mechanism. It is evident, therefore, that the expense of maintaining motor trucks will be greater than that of maintaining trailing trucks. It has not been possible, however, to obtain definite information with reference to the extent of this difference except in so far as the wear of brake shoes is concerned. For the purposes of these estimates it is assumed that the expense of maintaining the motor trucks will bear the same ratio to the expense of maintaining the trailer trucks as the first cost of the motor truck bears to the first cost of the trailer truck. Since there are no essential differences in the car bodies of motor cars and trailer cars, the extra expense of repairs to motor trucks will be indicated by the ratio between the first cost of motor car bodies and trucks and that of trailer car bodies and trucks. The difference in first cost of motor and trailer car bodies and trucks is about 4, 5 and 6 per cent, respectively, for the 600-volt direct current, the 11,000-volt alternating current and the 2,400-volt direct current systems. The application of these percentage increases to the expense of repairs to trailer cars gives unit increases in the expense of repairs to motor cars due to the differences in trucks as follows:

	CENTS PER CAR-MILE
For the 600-volt direct current system, 4 per cent of 1.107 or	0.044
For the 11,000-volt alternating current system, 5 per cent of 1.107 or	0.055
For the 2,400-volt direct current system, 6 per cent of 1.107 or	0.066

Multiple-unit motor cars are equipped with an air compressor and governor, an engineer's valve, feed valves, piping and other equipment not required on trailer cars. This additional brake mechanism involves an increase in the expense of maintaining motor cars as compared with that of maintaining trailer cars. It is reported that the expense on the Interborough Subway, New York City, of maintaining air brakes on motor cars is 205 per cent greater than that of maintaining brakes on trailer cars. An analysis of the results of operation on the Interborough Subway and on the Long Island Railroad indicates that the extra expense of maintaining the brake mechanism of motor cars, as compared with that of maintaining the brake mechanism of trailer cars, is as follows:

	CENTS PER CAR-MILE
For brake shoes	0.043
For air brakes and compressor	0.117
Total	0.160

The expense of maintaining motor car electric apparatus for the low voltage direct current system of operation, as shown by an analysis of expenses reported for the Long Island Railroad, the West Jersey & Seashore Railroad and the Interborough Subway, has been made the basis of the estimates of such expense for the proposed electric operation in Chicago. The expense of maintenance and inspection of electric apparatus of motor cars on these roads is as follows:

	CENTS PER CAR-MILE
Long Island Railroad	0.600
West Jersey & Seashore Railroad	0.830
Interborough Subway, New York	0.486

It is reported that this item of expense on the New York, Westchester & Boston Railroad, which operates a single-phase alternating current system, amounts to 0.72 cent per car-mile.

It is probable that the expense of this item, as reported for the Interborough Subway, is lower than could be obtained under conditions which exist in surface operation. The subway system is a very compact one. The car-mileage per unit of equipment is very high and the unit expense of maintenance and inspection is correspondingly low. The expense of this item as reported for the West Jersey & Seashore Railroad is believed to be high for average conditions. The West Jersey & Seashore Railroad operates through a territory possessing a sandy soil which has the effect of causing excessive wear on motor axle bearings. With consideration to these and other factors which have influenced the expense of this item as reported for existing systems, the estimated expense of maintaining electric apparatus of multiple-unit motor cars, under the proposed 600-volt direct current electric operation of the Chicago terminals, has been fixed at 0.7 cent per car-mile.

Information relating to the expense of maintaining electric apparatus of motor cars used on the single-phase alternating current system or on the 2,400-volt direct current system is very limited. The expense as reported for the New York, Westchester & Boston Railroad's single-phase operation is 0.72 cent per car-mile, or 20 per cent more than that reported for the Long Island Railroad's 600-volt direct current operation. A careful analysis has been made of the available figures and, for the purposes of these estimates, a difference of 20 per cent has been accepted. On this basis the cost of maintaining electric equipment for single-phase alternating current multiple-unit cars is 0.84 cent per car-mile.

The 2,400-volt direct current system of operation requires the use of cars equipped with four motors instead of two. This factor presents greater complication in the control mechanism and greater difficulty in maintaining the insulation. There appears to be no question that the expense of maintenance of electric equipment for 2,400-volt direct current motor cars will be greater than that of maintaining electric equipment for alternating current motor cars; but in view of the fact that there are no data available from actual experience, the estimated maintenance expense of 0.84 cent per car-mile as determined for the single-phase motor car has been accepted as applicable to the 2,400-volt direct current motor car.

In this analysis no consideration has been given to the possible difference in the cost of maintaining electric heating and lighting apparatus, as compared with the cost of maintaining the present steam heating and gas lighting apparatus.

A summary of these estimated increases in the expense of repairs per motor car-mile for mechanical and electrical parts, in addition to the expense per car-mile for repairs to car body and ordinary running gear, is presented in table CCCXCIX.

TABLE CCCXCIX. ESTIMATED INCREASE IN EXPENSE OF REPAIRS TO MOTOR AND TRAILER CARS (EXCLUSIVE OF REPAIRS TO CAR BODY AND ORDINARY RUNNING GEAR)

System	Cents per Car-Mile		
	Mechanical	Electrical	Total
1	2	3	4
600-volt direct current.............	0.204	0.700	0.904
2,400-volt direct current...........	0.226	0.840	1.066
11,000-volt alternating current.....	0.215	0.840	1.055

The addition of these unit increases to the estimated expense per car-mile for repairs to body and ordinary running gear yields results as shown by table CD.

The number of car-miles performed in suburban passenger service in the Chicago terminals during the year 1912 and the estimated number of multiple-unit motor and trailer car-miles required for the electric operation of a service identical in volume and quality, over the same trackage, are shown in the following:

	CAR-MILES
Suburban passenger service, steam operation	18,727,420
Multiple-unit trailer car-miles, electric operation	6,056,080
Multiple-unit motor car-miles, electric operation	12,671,340

TABLE CD. ESTIMATED TOTAL EXPENSE PER MOTOR CAR-MILE FOR REPAIRS TO MOTOR CARS

System	Expense per Car-Mile for Body and Ordinary Running Gear, Cents	Excess Expense per Motor Car-Mile for Mechanical and Electrical Parts, Cents	Total Expense per Motor Car-Mile for Repairs to Motor Cars, Cents
1	2	3	4
600-volt, D. C	1.107	.904	2.011
2,400-volt, D. C	1.107	1.066	2.173
11,000-volt, A. C	1.107	1.055	2.162

The application, to the mileage performed in the year 1912, of the unit expenses of maintaining cars in the present steam suburban passenger service and in the proposed multiple-unit passenger service, yields results as shown by table CDI.

TABLE CDI. ESTIMATED TOTAL EXPENSE OF MAINTAINING STEAM PASSENGER CARS AND MULTIPLE-UNIT MOTOR AND TRAILER CARS

(Basis of 1912)

Item	Cents per Car-Mile	Steam 1912	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4	5
Trailer cars	1.107	$207,313	$ 67,041	$ 67,041
Motor cars	2.173		275,348	
Motor cars	2.162			273,954
Totals		$207,313	$342,389	$340,995

The estimated expense of multiple-unit motor and trailer car repairs and maintenance on the Chicago & North Western Railway for steam and for 600-volt operation, based upon the units previously set forth and the service requirements of the year 1912, is shown by table CDII.

TABLE CDII. ESTIMATED TOTAL EXPENSE OF MAINTAINING STEAM PASSENGER CARS AND MULTIPLE-UNIT MOTOR AND TRAILER CARS, CHICAGO & NORTH WESTERN RAILWAY

(Basis of 1912)

Item	Cents per Car-Mile	Steam 1912	600-Volt D. C.
1	2	3	4
Trailer cars	1.107	$64,418	$ 16,105
Motor cars	2.011		87,768
Totals		$64,418	$103,873

Account No. 33—Passenger Train Cars, Depreciation. Account No. 39—Electric Equipment of Cars, Depreciation: The proposed change from steam to electric operation will involve no changes in the charges due to depreciation of car bodies. There will, however, be an added depreciation due to the heavier trucks and the more complicated apparatus of motor cars. The effect of these factors upon depreciation charges under these two accounts is considered elsewhere in this report (chapter 401).

Account No. 40—Floating Equipment, Repairs: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 41—Floating Equipment, Renewals: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 42—Floating Equipment, Depreciation: The proposed change from steam to electric operation will involve no change in the charges to this account.

Account No. 43—Work Equipment, Repairs: The proposed change from steam to electric operation will necessitate the acquisition of certain additional work and inspection equipment (section 213.066). The expense of maintenance of this equipment has not been determined, the amount being obviously small.

Account No. 44—Work Equipment, Renewals: As in the case of Account No. 43, no estimate has been made of the effect of the change from steam to electric operation upon the expenditures chargeable to this account. The additional expense under electric operation will be slight, and, for the purposes of these estimates, it is regarded as negligible.

Account No. 45—Work Equipment, Depreciation: No determinations have been made, in connection with these analyses of operating expense accounts, of the effect of the proposed change from steam to electric operation upon the amounts chargeable to depreciation. The subject of depreciation is elsewhere considered (chapter 401).

Account No. 46—Shop Machinery and Tools: The proposed change from steam to electric operation will necessitate the acquisition of certain machinery and tools required for the care of electric equipment. Under electric operation, also, some of the equipment now needed for the maintenance of steam equipment may be disposed of or transferred to new locations. The net effect of the proposed change upon the expenditures chargeable to shop machinery and tools is regarded as negligible and no definite values have been determined.

Account No. 47-A and 86 — Substations, Operation and Maintenance. Account No. 47-B and 86 — Power Station, Operation and Maintenance: The installation and operation of any of the proposed systems of electric traction will, under the plan of the Committee, involve the operation and maintenance of a central power station and of a number of substations, as set forth in the Committee's specifications and estimates of installation costs (chapter 213). These factors will introduce new items of operating expense which do not exist under the present steam operation. The Committee's estimates of the expense of operation and maintenance of power station and substations for the proposed electric operation of the Chicago railroad terminals are based upon a study of operating and maintenance expenses of such facilities on roads now operating electric traction systems elsewhere, full consideration having been given in each study to all influencing differences in conditions.

Each of the three systems of electric operation considered in the estimates will involve certain differences in power station and substation equipment, and the expense of maintenance and operation for each system must therefore be studied separately.

Substations for direct current operation are necessarily of large capacity. Those to be provided for the operation of the Chicago railroad terminals will involve operating expenditures comparable with those of substations used for heavy urban traction work or heavy traffic terminal sections of electrified railroads operating elsewhere. The actual costs of operation and maintenance of the substations of the Long Island Railroad in Brooklyn and Queens, of the Pennsylvania Terminal, New York, of the New York Subway, and of the Manhattan Elevated Lines have been obtained. These are shown by table CDIII.

TABLE CDIII. EXPENSE OF OPERATION AND MAINTENANCE OF SUBSTATIONS, AS REPORTED BY RAILROADS OPERATING ELECTRIC TRACTION SYSTEMS

Railroad	Substations Nos.	Expense per Substation, per Annum
1	2	3
Long Island Railroad	1 to 4	$ 8,540
Pennsylvania Terminal, New York	2, 3 and 4	7,650
Manhattan Elevated	....	10,300
New York Subway	....	10,100

All of these electric traction systems operate with low voltage direct current on a third rail contact system. Three shifts per day with two men on each of two shifts and frequently with two men on all three shifts are generally employed at each substation. The greater part of the total operating and maintenance expense consists of labor. For this reason the size of units and the total kilowatt capacity provided are not of first importance in determining maintenance and operating expenses, since the effect of capacity upon the cost of labor is slight and the total expense of materials for repairs is comparatively small. For the purposes of these estimates the annual expense of operation and maintenance of substations for the 600-volt direct current system has been fixed at $7,400 per station.

With the proposed 2,400-volt direct current system of traction each unit will consist of two 1,200-volt machines operated in series. This factor will tend to increase the unit expense of maintenance and operation, and there will probably be an increase also in the cost of repairs due to the high voltage current collection at the commutator. The average annual expense of operation and maintenance will be dependent to some extent upon the capacity of the substation. Based upon a study of the expense of substation operation and maintenance on other systems, the estimated annual expense per substation for the proposed 2,400-volt direct current operation on the Chicago terminals has been fixed as follows:

CAPACITY OF SUBSTATION	EXPENSE PER SUBSTATION PER ANNUM
From 3,000 to 7,000 kw.	$ 4,500
From 8,000 to 15,000 kw.	8,000
From 16,000 to 35,000 kw.	10,500

With the single-phase alternating current system of traction, substations are not equipped with moving machinery and no regular attendance is required. The switches are arranged for remote control from the nearest signal tower. The labor required for operation is therefore reduced to a force sufficient for the periodical general inspection of each substation and for the handling of emergency repairs when trouble is reported by the towerman or the power director. In addition to this labor expense, the actual cost of materials for repairing the apparatus must be considered.

While there are no available records of the cost of maintenance and operation of single-phase substations on steam railroad electrifications, there are many examples of this type of substation in use on high tension transmission power lines. The New York, New Haven & Hartford Railroad and the New York, Westchester & Boston Railway have until recently fed power direct from the power house to the contact system. The estimated cost of maintenance and operation of single-phase substations for the proposed electrification of Chicago's railroad terminals has been fixed by analyzing the conditions to be met, and the figures thus obtained have been compared with the reported expense of substation operation and maintenance on existing high tension transmission lines. Owing to the compact arrangement of the Chicago terminals, it will be possible to use the same general organization for the inspection and maintenance of substations, transmission lines and contact system. It will be possible to establish headquarters for overhead maintenance crews at certain convenient points near substations. A certain amount of the time of each crew will be spent in waiting for emergency calls, and such spare time may be utilized in the inspection of the substation located at the crew's headquarters and probably of the one on either side of its headquarters. Other substations may be inspected periodically by regular switchboard maintainers. It is estimated that the expense of repairing the substation apparatus, based upon the expense of similar repair items in direct current substations, will be $250 per substation per annum. To this should be added one-third of the time of a switchboard maintainer, it being assumed that one man will be able to care for three substations. Upon a basis of $900 per year per maintainer, the cost per substation per year will be $300. For the purpose of these estimates, therefore, the total annual expense of maintenance and inspection of single-phase substations has been fixed at $550 per substation.

A summary of the estimated annual expense of maintenance and operation of substations for each of the proposed electric traction systems, on the basis of conditions obtaining in the Chicago terminals in 1912, is presented in table CDIV.

TABLE CDIV. ESTIMATED ANNUAL EXPENSE OF MAINTENANCE AND OPERATION OF SUBSTATIONS, BY SYSTEMS

(Basis of 1912)

System	Capacity, Kilowatts	Annual Expense per Substation
1	2	3
600-Volt, D. C.	....	$ 7,400
2,400-Volt, D. C.	3,000 to 7,000	4,500
	8,000 to 15,000	8,000
	16,000 to 35,000	10,500
11,000-Volt, A. C.	....	550

The total estimated annual expense of operation and maintenance of substations for the proposed 2,400-volt direct current system for all roads is shown by the following:

3 substations at $4,500 each per annum	$13,500
3 substations at $8,000 each per annum	24,000
5 substations at $10,500 each per annum	52,500
Total (11 substations)	$90,000

Under the proposed 11,000-volt alternating current system of traction for the electrification of all roads involved, 31 substations will be required. The annual expense of operation and maintenance per substation has been fixed at $550, and the total for all roads will, therefore, be $17,050 per annum.

The estimated annual expense of operation and maintenance of substations by services is distributed as shown by table CDV.

TABLE CDV. ESTIMATED ANNUAL EXPENSE OF OPERATION AND MAINTENANCE OF SUBSTATIONS, BY SYSTEMS AND BY SERVICES — ALL ROADS

(Basis of 1912)

Service	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3
Through passenger	$14,310	$ 2,780
Suburban passenger	12,726	2,182
Road freight	9,432	2,023
Yard and transfer	53,532	10,059
Totals	$90,000	$17,050

The unit cost of maintaining and operating the central power station for the proposed electric operation of Chicago's railroad terminals, has been fixed at 0.3 cent per kilowatt-hour. This includes the cost of labor, materials and supplies for maintenance and operation. It does not include any overhead expense outside of the building but does include the expense of maintaining the building. This expense per kilowatt-hour is subdivided as follows:

	CENTS
Operating labor	0.0400
Fuel and water	0.2194
Lubricants and operating supplies	0.0146
Maintenance materials and labor	0.0260
Total	0.3000

Based upon the unit cost of power per kilowatt-hour and upon the power requirements of 1912, the total annual expense of operation and maintenance of the single power station for all roads operating in the Chicago terminals, for the 2,400-volt direct current and the 11,000-volt alternating current systems, has been determined as set forth by table CDVI.

TABLE CDVI. ESTIMATED TOTAL ANNUAL EXPENSE OF OPERATION AND MAINTENANCE OF POWER STATION — ALL ROADS

(Basis of 1912)

System	Requirements Kilowatt-hours	Total Annual Expense
1	2	3
2,400-Volt, D. C.	688,600,000	2,065,827
11,000-Volt, A. C	644,298,000	1,932,894

The total expense for operation and maintenance of power station, by services, is shown by table CDVII.

TABLE CDVII. ESTIMATED TOTAL ANNUAL EXPENSE OF OPERATION AND MAINTENANCE OF POWER STATION, BY SERVICES — ALL ROADS

(Basis of 1912)

Service	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3
Through passenger	$ 328,466	$ 307,717
Suburban passenger	292,108	247,032
Road freight	216,499	223,443
Yard, including transfer	1,228,754	1,160,702
Totals	$2,065,827	$1,932,894

The total estimated expense of operation and maintenance of the substations for the 600-volt direct current third rail operation of the Chicago & North Western Railway is based upon the use of 14 substations at an annual expense of $7,400 per year per substation, or a total expense of $103,600.

The total estimated annual expense of operation and maintenance of the power station for 600-volt direct current third rail operation of the Chicago & North Western Railway is based upon an estimated output of 132,968,000 kilowatt-hours required to handle the traffic of the year 1912 at 0.3 cent per kilowatt-hour, or a total expense of $398,904. These expenses have been employed in the determination of the total expense of operating all roads by the 600-volt direct current system, in the manner hereinbefore described (section 301.04).

Account No. 48—Injuries to Persons: For the purposes of these estimates, it has been assumed that the proposed change from steam to electric operation will involve no change in the charges to this account. The subject of "Injuries to Persons" is more fully considered elsewhere in this report (chapter 303.)

Account No. 49—Stationery and Printing: The proposed change from steam to electric operation will involve no change in expenditures chargeable to this account.

Account No. 50—Other Expenses: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 51—Maintaining Joint Equipment at Terminals, Dr.: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 52—Maintaining Joint Equipment at Terminals, Cr.: The proposed change from steam to electric operation will involve no change in the charges to this account.

3. *Traffic Expenses*

Account No. 53—Superintendence. Account No. 54—Outside Agencies. Account No. 55—Advertising. Account No. 56—Traffic Associations. Account No. 57—Fast Freight Lines. Account No. 58—Industrial and Immigration Bureaus. Account No. 59—Stationery and Printing. Account No. 60—Other Expenses: The proposed change from steam to electric operation will involve no apparent change in the expenditures chargeable to these accounts, and for purposes of these estimates it has been assumed that the charges subsequent to electrification will be the same as those which now accrue under steam operation.

4. *Transportation Expenses*

Account No. 61—Superintendence: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 62—Dispatching Trains: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 63—Station Employes: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 64—Weighing and Car Service Associations: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 65—Coal and Ore Docks: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 66—Station Supplies and Expenses: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account. (See section 301.08.)

Account No. 67—Yard Masters and Their Clerks: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 68—Yard Conductors and Brakemen: The proposed change from steam to electric operation will effect no change in the expenditures chargeable to this primary account except in the case of suburban passenger service. Under the present steam operation, the handling of suburban passenger trains at terminals is generally accomplished by the use of a yard or switching locomotive which removes the train from the inbound track and places it on the outbound track. When the train is removed from the inbound track, the locomotive which hauled it is free to pass out to a crossover through which it may proceed to an outbound track and there couple to an outbound train previously placed in position by a switching locomotive. The switching locomotive used for this purpose also performs other work in connection with suburban passenger equipment, such as the movement of cars to and from the coach yard.

With the use of electric multiple-unit equipment for suburban passenger service, each train will include motor cars which will take the place of the steam locomotive now used. These motor cars are capable of performing most of the switching in connection with this equipment.

After a careful study of physical conditions and service requirements at each of the railroad terminals of Chicago in which, under electrification, multiple-unit service will be operated, it is estimated that 50 per cent of the present locomotive switching service in connection with the handling of suburban passenger trains will be eliminated upon the introduction of the multiple-unit equipment.

Reports supplied by the railroads operating suburban passenger service within the proposed limits of electrification show that the expense of switching suburban passenger trains during the year 1912 amounted to $53,636. The estimated saving in the expenses chargeable to this account which will result from the introduction of multiple-unit trains in suburban passenger service will, therefore, be $26,818.

For the Chicago & North Western Railway the expense of switching suburban passenger trains during the year 1912 amounted to $19,087. The estimated saving in expense chargeable to this account upon the introduction of multiple-unit trains in suburban passenger service will therefore be $9,543. This estimate has been employed in the determination of the total expense of operating all roads by the 600-volt direct current system, in the manner hereinbefore described (section 301.04).

Account No. 69—Yard Switch and Signal Tenders: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 70—Yard Supplies and Expenses: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account. (See section 301.08.)

Account No. 71—Yard Enginemen: The proposed change from steam to electric operation will, as in the case of expenditures chargeable to Account No. 68, result in a reduction of expenses incident to the switching of suburban passenger trains at terminals. The charges to this account in 1912 for all roads amounted to $42,539. On the basis of the estimated reduction of 50 per cent, the charges to this account after the introduction of multiple-unit equipment in suburban passenger service will be $21,270.

The charges to this account for the Chicago & North Western Railway for the year 1912 amounted to $10,009. Charges to this account after the introduction of multiple-unit equipment in suburban passenger service will be $5,004.

This estimate has been employed in the determination of the total expense of operating all roads by the 600-volt direct current system, in the manner hereinbefore described.

Account No. 72—Engine House Expense, Yard: The proposed change from steam to electric operation will involve the elimination of the steam locomotive from the trackage to be electrified and the substitution therefor of electric locomotives and multiple-unit motor cars. Expenses chargeable to this account under the present steam operation within the proposed limits of electrification will be eliminated and a part of these will be transferred to the steam operated divisions outside of the proposed limits of electrification (section 301.09). Certain expenditures chargeable to this account for electric yard locomotives within the proposed limits of electrification will be introduced.

Reports furnished by the railroads indicate that the total expenditures chargeable to this account during the year 1912 amounted to $633,482. No segregation of this expense to show the charges to different services is given. The amount expended for yard conductors, yard brakemen and yard enginemen in suburban passenger service, Accounts Nos. 68 and 71, amounted to approximately 10 per cent of the total expenditures charged to those accounts. For the purpose of these estimates, therefore, it is assumed that an amount equal to 10 per cent of the total reported expenditures chargeable to this account for steam operation is properly chargeable to suburban passenger service.

It is apparent that the introduction of multiple-unit equipment in suburban passenger service will reduce the time now consumed by yard switching locomotives in the handling of suburban passenger cars, the motor cars being capable of performing most of the switching movements incident to the operation of suburban service. It is estimated that this reduction in time will amount to one-half. It is therefore assumed that under electrification the engine house expense of yard engines chargeable to suburban passenger service will be one-twentieth of the total expense chargeable to this account for all services.

The introduction of electric operation will also result in a reduction in the total engine house expense. The engine house expense on the Terminal Division of the Pennsylvania Railroad in New York is reported to be approximately one-fifth of the engine house expense under steam operation in 1912. The engine house expense on this division amounted to 0.58 cent per locomotive-mile, while that on the New Jersey steam operated division of the same railroad amounted to 2.59 cents per locomotive-mile. For purposes of these estimates it is assumed that the engine house expense for electric yard locomotives will be one-fifth of the present engine house expense for steam locomotives.

The application of the percentages indicated by this analysis to the reported engine house expense for yard locomotives under the steam operation in 1912 within the proposed limits of electrification yields results as shown by table CDVIII.

TABLE CDVIII. ESTIMATED ANNUAL EXPENSE UNDER ACCOUNT No. 72—ENGINE HOUSE EXPENSE FOR YARD LOCOMOTIVES, STEAM AND ELECTRIC OPERATION, ALL ROADS
(Basis of 1912)

Service	Steam	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Suburban passenger	$ 63,348	$ 6,335	$ 6,335
Yard and transfer	570,134	120,361	120,361
Totals	$633,482	$126,696	$126,696

The engine house expense for yard locomotives for 600-volt direct current third rail operation on the Chicago & North Western Railway will bear the same ratio to the corresponding expense of steam operation as is indicated for the 2,400-volt direct current and the 11,000-volt alternating current systems for all roads. This ratio for the 600-volt direct current operation has been applied to the expenditures chargeable to this account on the Chicago & North Western Railway in 1912 with results which are shown by table CDIX.

TABLE CDIX. ESTIMATED ENGINE HOUSE EXPENSE, CHICAGO & NORTH WESTERN RAILWAY
(Basis of 1912)

Service	Steam 1912	600-Volt D. C.
1	2	3
Suburban passenger	$ 9,942	$ 994
Yards, including transfer	89,475	18,889
Totals	$99,417	$19,883

This estimate has been used in the determination of the total expense under this account for all roads for the 600-volt direct current system, in the manner hereinbefore described (section 301.04).

The additional expenditures chargeable to this account for operation outside of the proposed limits of electrification are considered elsewhere (section 301.09).

Account No. 73 — Fuel for Yard Locomotives: The proposed change from steam to electric operation will result in the elimination of all steam locomotives from the trackage to be electrified, and consequently the cost of the fuel now consumed by locomotives within the proposed limits of electrification will be eliminated. The amount of fuel consumed by steam locomotives in yard service in 1912 within the Committee's Area of Investigation (Zones A and B) was determined as a result of the Committee's investigation of fuel consumption (chapter 104). In this investigation the railroad lines were divided into route elements and an accurate determination of the amount of fuel consumed by locomotives operating on each route element and on each railroad was made. The number of train-miles of service performed on each route element and on each railroad was also determined (chapter 201). It was possible from these determinations to establish the ratio between the service performed within the proposed limits of electrification and that performed within the Committee's entire Area of Investigation. This ratio was found to be 91.8 per cent. It was assumed that the amount of fuel consumed was proportionate to the amount of service performed. Therefore this factor of 91.8 per cent was applied to the amount of fuel consumed by yard locomotives within the Committee's Area of Investigation to determine the amount of fuel consumed by yard locomotives within the proposed limits of electrification. By this method it was shown that, during the year 1912, yard locomotives consumed a total of 1,950,707 tons of fuel within the proposed limits of electrification.

The average cost of fuel per ton was determined from reports submitted by the railroads. The cost of fuel per ton for yard locomotives, as reported by each railroad, was multiplied by the number of locomotive-miles performed in yard service by the railroad in question within the Committee's Area of Investigation, and the sum of such products for all roads reporting was divided by the total number of locomotive-miles performed in yard service, the result being accepted as the average cost per ton of fuel for all roads. The average cost of coal for yard service was found to be $2.09 per ton. This unit cost, when applied to the total amount of fuel consumed by yard locomotives within the proposed limits of electrification, indicated that the total amount expended in 1912 for fuel for yard locomotives was $4,076,978.

As under other similar accounts, 10 per cent of this total expense, or $407,698, has been regarded as chargeable to suburban passenger service and the balance of $3,669,280 to yard and transfer service.

It has been determined that the cost of fuel for yard locomotives on the Chicago & North Western Railway in 1912 amounted to $534,852, of which amount $53,485 was chargeable to suburban passenger service and $481,367 to yard and transfer service. These estimates have been used in the determination of the total expense under this account to all roads for 600-volt direct current operation, in the manner hereinbefore described (section 301.04).

As a result of electrification the entire expense chargeable to this account will be eliminated.

Account No. 74 — Water for Yard Locomotives: The proposed change from steam to electric operation will involve the elimination of all steam locomotives from the trackage to be electrified. Subsequent to electrification, therefore, there will be no expense incident to the supplying of water for yard locomotives for use within the proposed limits of electrification. Under the present method of steam operation, however, certain yard locomotives which receive water and other supplies within the proposed limits of electrification, operate in steam service outside of these limits, and the expense of supplying water for such locomotives for use beyond the limits of electrification will continue subsequent to the inauguration of electric operation.

Based upon reports furnished by the railroads, it has been determined that the total expense of supplying water to yard locomotives within the limits of electrification during the year 1912 was $137,044. As in the case of other similar accounts, it is assumed that one-tenth of this amount, or $13,704, is chargeable to suburban passenger service. The proportions chargeable to other services have not been determined.

The total expense of supplying water to yard locomotives within the proposed limits of electrification for the Chicago & North Western Railway for the year 1912 was $28,633, of which 10 per cent, or $2,863, is chargeable to suburban passenger service.

Upon the introduction of electric operation practically all of this expense will be eliminated. The small portion representing the cost of water supplied to yard locomotives within the limits of electrification, and used by them outside these limits, is elsewhere considered (section 301.09).

Account No. 75—Lubricants for Yard Locomotives: A comparison of the cost of lubricants for electric locomotives and for steam locomotives, as shown by the records available, indicates that the proposed change from steam to electric operation will involve so slight a change in the expenditures chargeable to this account that the amount is regarded as negligible. It is reported that the cost of lubricants for electric locomotives on the Pennsylvania Railroad's New York terminal electrification amounts to 0.25 cent per locomotive-mile, and that the average cost of lubricants for steam locomotives on all steam operated divisions of the Pennsylvania Railroad amounts to 0.24 cent per locomotive-mile. For purposes of these estimates, therefore, it is assumed that the cost of lubricants will be the same for both steam and electric yard locomotives.

Account No. 76—Other Supplies for Yard Locomotives: It has been difficult to obtain from existing records any very complete or definite figures relating to the cost of miscellaneous supplies for yard locomotives. A study of the conditions obtaining under steam and electric operation indicates that most of the supplies chargeable to this account for steam operation are also needed for electric operation. Those supplies which are needed in connection with locomotive fire-boxes, boilers, and mechanisms peculiar to the steam locomotive will, of course, not be needed for electric locomotives; but electric locomotives will require certain special supplies which are not needed for steam locomotives. For purposes of these estimates, therefore, it is assumed that any change in the expenditures chargeable to this account will be negligible and no determinations have been made.

Account No. 77—Operating Joint Yards and Terminals, Dr.: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 78—Operating Joint Yards and Terminals, Cr.: The proposed change from steam to electric operation will involve no change under this account.

Account No. 79—Motormen. Account No. 80—Road Enginemen: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account for the operation of any service except the suburban passenger service. Under the proposed method of electric operation, suburban passenger service will be handled by multiple-unit motor and trailer cars instead of by locomotives. In place of the two men now required on steam suburban passenger locomotives, the operation of multiple-unit trains will require only one man, a motorman.

Based upon reports furnished by the railroads, it has been determined that the average expense due to enginemen and firemen on suburban passenger locomotives in the year 1912 amounted to 8.54 cents per locomotive-mile. The estimated expense of a motorman on suburban multiple-unit trains under electric operation has been fixed at 4.675 cents per train-mile. This unit is based upon a rate of pay of $4.25 per 100 miles or less, which rate is in accordance with the rates now paid motormen operating gasoline or self-propelled motor cars on railroads where such cars are in use. To this rate has been added 10 per cent to allow for overtime and for time consumed in make-up and put-away service. The reduction in expenditures chargeable to this account, which will result from the introduction of electric operation, will therefore amount to 3.865 cents per train-mile. During the year 1912 a total of 4,239,110 locomotive-miles was performed in suburban passenger service. On this basis the reduction in this expense will amount to $163,842.

In 1912 the expense chargeable to steam operation within the proposed limits of electrification on the Chicago & North Western Railway under this account amounted to $78,210. Under electric operation the expense chargeable to this account will amount to $56,950.

Account No. 81—Engine House Expense, Road: The proposed change from steam to electric operation will involve the elimination of the steam locomotive from the trackage within the proposed limits of electrification and the substitution therefor of electric locomotives and multiple-unit motor cars. Expenses chargeable to this account under the present steam operation within the proposed limits of electrification will be eliminated, and a part of these will be transferred to the steam operated divisions beyond the proposed limits of electrification (section 301.09). Certain expenditures chargeable to this account for electric road locomotives within the proposed limits of electrification will be introduced.

Each of the 25 railroads reporting gave the expenditures chargeable to this account during the year 1912 for steam operation within the Committee's Area of Investigation. The total of the amounts so reported was $623,991. The total of the expenditures reported by each road was prorated to the several road services of the road in question upon the basis of the locomotive-mileage performed in each service. The expenditures for each service were totaled for all roads reporting, and these totals were divided by the number of locomotive-miles performed in the service in question within the Committee's Area of Investigation to give the unit expense chargeable to this account for each service. •By this process units for road engine house expense in the several services were determined as follows:

	CENTS PER LOCOMOTIVE-MILE
Through passenger	4.790
Suburban passenger	6.221
Road freight	7.050
Average	5.696

These units were applied to the locomotive-mileage performed by all roads in each of the several services during the year 1912, within the proposed limits of electrification, to obtain the total expenditures chargeable to this account.

The engine house expense involved in the care of electric locomotives will be materially less than that shown for steam locomotives. The engine house expense on the Terminal Division of the Pennsylvania Railroad in New York is reported to be approximately one-fifth of the engine house expense under steam operation. In 1912 the engine house expense on this electrically operated division amounted to 0.58 cent per locomotive-mile, while that on the New Jersey steam operated division of the same railroad amounted to 2.59 cents per locomotive-mile. For purposes of these estimates it is assumed that the engine house expense for electric road locomotives and for electric multiple-unit motor cars used in suburban service will be one-fifth of the present engine house expense involved in caring for steam locomotives. On this basis the total road engine house expense for electric operation, with the corresponding expense for steam operation, has been determined as shown by table CDX.

TABLE CDX. ESTIMATED ANNUAL EXPENSE UNDER ACCOUNT NO. 81 — ENGINE HOUSE EXPENSE — FOR STEAM AND FOR ELECTRIC OPERATION, ALL ROADS
(Basis of 1912)

Service	Steam	2,400-Volt D. C.	1,000-Volt A. C.
1	2	3	4
Through passenger	$258,039	$51,608	$51,608
Suburban passenger	263,715	52,742	52,742
Road freight	138,158	27,632	27,632
Totals	$659,912	$131,982	$131,982

The engine house expense for road locomotives for the 600-volt direct current system of operation will bear the same ratio to the corresponding expense of steam operation as is indicated for the 2,400-volt direct current and the 11,000-volt alternating current systems.

This estimated expense of 600-volt direct current operation, for the Chicago & North Western Railway on the basis of service requirements of 1912, amounts to $43,246. The cost for steam operation under this account was $216,230.

The additional expenditures chargeable to this account for steam operation outside of the proposed limits of electrification are elsewhere considered (section 301.09).

Account No. 82—Fuel for Road Locomotives: The proposed change from steam to electric operation will result in the elimination of all steam locomotives from the trackage to be electrified, and consequently the cost of fuel now consumed within the proposed limits of electrification will be eliminated. The amount of fuel consumed by steam road locomotives in the year 1912 within the Committee's Area of Investigation (Zones A and B) was determined as a result of the Committee's investigation of fuel consumption (chapter 104). In this investigation the railroad lines were divided into route elements and an accurate determination was made of the amount of fuel consumed by locomotives while operating on each route element and on each road. The number of train-miles of service performed on each route element and on each railroad was also determined as explained elsewhere (chapter 202). It was possible, as a result of these determinations, to establish the ratio between the service performed within the proposed limits of electrification and the service performed within the Area of Investigation. This ratio was found to be 91.8 per cent. It was assumed that the amount of fuel consumed was proportionate to the amount of service performed. Therefore this factor of 91.8 per cent was applied to the amount of fuel consumed by road locomotives in service within the Area of Investigation, to determine the amount of fuel consumed by road locomotives within the proposed limits of electrification. By this method it was found that road locomotives consumed a total of 633,830 tons within the proposed limits of electrification during the year 1912.

The average cost of fuel per ton was determined from reports submitted by the railroads. The cost of fuel per ton for road locomotives as reported by each railroad was multiplied by the number of locomotive-miles performed by each railroad within the Area of Investigation, and the sum of such products for all roads reporting was divided by the total number of locomotive-miles performed by these roads in road service, the result being accepted as the average cost per ton of fuel for all roads. This average cost for road service was found to be $1.903 per ton. This unit cost of fuel, when applied to the total amount of fuel consumed by all road locomotives within the proposed limits of electrification, indicated that the total amount expended in 1912 for each of the road services was as follows:

Through passenger	$419,771
Suburban passenger	334,317
Road freight	452,090
Total	$1,206,178

Under conditions obtaining in 1912 the expense of fuel for road locomotives chargeable to this account for the Chicago & North Western Railway amounted to $432,058.

As a result of electrification the entire expense chargeable to this account will be eliminated.

Account No. 83—Water for Road Locomotives: The proposed change from steam to electric operation will involve the elimination of all steam locomotives from the trackage to be electrified. After the inauguration of electric operation there will be no expense incident to the supplying of water for road locomotives for use within the proposed limits of electrification. Under the present method of steam operation, however, certain road locomotives which receive water and other supplies within the proposed limits of electrification operate in steam service outside of these limits, and the expense of supplying water for such locomotives for use outside of the limits of electrification will continue after the introduction of electric operation.

Based upon reports furnished by the railroads, it has been determined that the total expense of supplying water to road locomotives within the proposed limits of electrification during the year 1912 was $116,508. This amount has been prorated to the several classes of road service on a locomotive-mileage basis, with results as follows:

Through passenger	$54,172
Suburban passenger	42,629
Road freight	19,707
Total	$116,508

The total expense chargeable under this account for operation on the Chicago & North Western Railway for the year 1912 amounted to $23,983.

Upon the introduction of electric operation practically all of this expense will be eliminated. The small portion representing the cost of water supplied to road locomotives within the proposed limits of electrification and used by them outside of such limits is considered elsewhere in this report (chapter 301.09).

Account No. 84—Lubricants for Road Locomotives: A comparison of the cost of lubricants for electric and steam locomotives, as shown by the records available, indicates that the proposed change from steam to electric operation will involve so slight a change in the expenditures chargeable to this account that the amount is regarded as negligible. It is reported that the cost of lubricants for electric locomotives on the Pennsylvania Railroad's New York terminal electrification amounts to 0.25 cent per locomotive-mile, and that the average cost of lubricants for steam locomotives on all steam operated divisions of the Pennsylvania Railroad amounts to 0.24 cent per locomotive-mile. For purposes of these estimates, therefore, it is assumed that the cost of lubricants will be the same for both steam and electric road locomotives.

Account No. 85—Other Supplies for Road Locomotives: It has been difficult to obtain from existing records any very complete or definite figures relating to the cost of miscellaneous supplies for road locomotives. A study of the conditions obtaining under steam and electric operation indicates that most of the supplies chargeable to this account for steam operation are also needed for electric operation. Those supplies which are needed in connection with locomotive fire-boxes, boilers and mechanisms peculiar to the steam locomotive will, of course, not be needed for the electric locomotive, but electric locomotives will require certain special supplies which are not needed for steam locomotives. For purposes of these estimates, therefore, it is assumed that any change in the expenditures chargeable to this account will be negligible and no determinations have been made.

Account No. 86—Operating Power Plants: The analysis of the charges to this account are considered in connection with those chargeable to the operation and maintenance of substations and power station (Accounts Nos. 47-A and 47-B).

Account No. 87—Purchased Power: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 88—Road Trainmen: The plans of the Committee do not contemplate any change in the number or pay of trainmen at present employed in the operation of steam trains, except in the case of suburban passenger service, which has elsewhere been considered (Account No. 79). The proposed change from steam to electric operation will therefore involve no change in the expenditures chargeable to this account.

Account No. 89—Train Supplies and Expenses: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 90—Interlockers, and Block and Other Signals, Operation: The proposed change from steam to electric operation will involve no change in the number or pay of operators or employes needed in connection with the operation of interlockers and signals. Therefore no change in the expenditures chargeable to this account will result from the introduction of electric operation.

Account No. 91—Crossing Flagmen and Gatemen: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 92—Drawbridge Operation: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 93—Clearing Wrecks: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 94—Telegraph and Telephone Operation: Reports furnished by the railroads indicate that the total expenditures chargeable to telegraph and telephone operation within the proposed limits of electrification during the year 1912 amounted to $117,373. This amount has been pro-rated on a locomotive-mileage basis to the four classes of service recognized, with results as follows:

Through passenger	$26,083
Suburban passenger	20,525
Road freight	9,488
Yard and transfer	61,277
Total	$117,373

The introduction of any of the proposed systems of electric operation will involve an increase in the expenditures chargeable to this account, owing to the necessity of providing telephone service for intercommunication between the power station, substations, dispatchers' headquarters and other points. Under the plan of the Committee, it is proposed that the instruments and telephone lines needed for this additional service are to be obtained from the local telephone company at a fixed unit rental charge. An exception to this plan has been made in the case of the line for the telephone patrol system. This line will be installed and maintained by the railroad companies. The expense of maintenance has been considered in the analysis of Account No. 14. The instruments for the patrol line are, however, to be rented, the rental of such instruments being included in the estimated additional expenses chargeable to this account.

According to the Committee's plan for the 2,400-volt direct current system of operation, there are to be 133 substations and switching stations, situated at an average distance of 12.4 miles from the switchboard of the power station. For the 11,000-volt alternating current system of traction there are to be 137 substations and switching stations, located at an average distance of 12.8 miles from the switchboard of the power station. Under both systems of operation, there will be required 35 private telephone lines from the power station switchboard to the switchboards of the dispatchers' offices or the general offices of the railroad companies. The average length of these lines will be eight miles. Under electric operation there will be 20 new locomotive or multiple-unit car terminals, which are to be provided with telephone service. Such service is to be obtained through the central exchanges of the local telephone company. According to the plan of the Committee, no telephone operators will be required at the outer end of any of these telephone circuits, it being assumed that attendants, such as substation operators, towermen, station agents, shop foreman and others may be reached without the aid of a switchboard operator. It is estimated that one telephone operator will be required at the power station, for each shift. The expense of operators for maintaining wire lines and supervising the operation of the telephone systems has been considered in connection with the operating expense of substations and power station (Accounts Nos. 47-A, 47-B and 86).

Estimates of the expense involved in the operation of additional telephone lines, which will be needed subsequent to electrification, have been based upon a careful study of the conditions to be met and upon unit costs in effect in 1912. Such units extended to cover the additional telephone and telegraph establishment required, and the total additional estimated expenditures chargeable to this account under electric operation, based upon the conditions of 1912, are presented in table CDXI.

TABLE CDXI. ESTIMATED INCREASE IN EXPENDITURES UNDER ACCOUNT No. 94 — TELEGRAPH AND TELEPHONE OPERATION, ALL ROADS

(Basis of 1912)

Item	Annual Rental	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Rent of private lines from power station switchboard to substations and switching stations, per mile..	$40.00	$65,968	$70,144
Rent of private lines from power station switchboard to general offices or dispatchers' offices, per mile...	40.00	11,200	11,200
Rent of telephones on patrol line, per instrument......................	6.00	6,780	6,780
Rent of telephones in substations, switching stations, power station, and dispatcher's office, per instrument..............................	6.00	1,128	1,152
Service and rent of instruments for new locomotive and car terminals, per station......................	40.00	4,800	4,800
Three operators at power station, per month each......................	65.00	2,340	2,340
Totals	....	$92,216	$96,416

These increased expenses for telegraph and telephone operation constitute additions to the present expense of such operation. The estimated total annual expenditures on the basis of the operations of 1912 will therefore be $209,589 for the 2,400-volt system and $213,789 for the 11,000-volt system. These totals, pro-rated on a locomotive-mileage basis to the four classes of service, with the corresponding amounts for steam operation in 1912, are shown by table CDXII.

TABLE CDXII. ESTIMATED ANNUAL EXPENSE UNDER ACCOUNT No. 94 — TELEGRAPH AND TELEPHONE OPERATION ALL ROADS

(Basis of 1912)

Service	Steam	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4
Through passenger................	$26,083	$ 46,573	$ 47,509
Suburban passenger..............	20,525	36,651	37,385
Road freight.	9,488	16,943	17,283
Yard and transfer................	61,277	109,419	111,612
Totals......................	$117,373	$209,589	$213,789

This account has also been analyzed for 600-volt direct current third rail operation on the Chicago & North Western Railway. The expense chargeable to this account under steam operation during 1912 amounted to $4,460. Electric operation will require an expense for telephone and telegraph operation of $24,688. This estimate has been used in determining the total expense under this account to all roads for 600-volt direct current operation, in the manner hereinbefore described (section 301.04).

Account No. 95—Operating Floating Equipment: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 96—Express Service: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 97—Stationery and Printing: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 98—Other Expenses: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 99—Loss and Damage, Freight: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 100—Loss and Damage, Baggage: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 101—Damage to Property: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 102—Damage to Stock on Right-of-Way: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 103—Injuries to Persons: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 104—Operating Joint Tracks and Facilities, Dr.: The proposed change from steam to electric operation will involve no change in the expenditures chargeable to this account.

Account No. 105—Operating Joint Tracks and Facilities, Cr.: The proposed change from steam to electric operation will involve no change in the charges to this account.

5. *General Expenses*

Account No. 106—Salaries and Expenses of General Officers. Account No. 107—Salaries and Expenses of Clerks and Attendants.. Account No. 108—General Office Supplies and Expenses. Account No. 109—Law Expenses. Account No. 110—Insurance. Account No. 111—Relief Department Expenses. Account No. 112—Pensions. Account No. 113—Stationery and Printing. Account No. 114—Other Expenses. Account No. 115—General Administration Joint Tracks, Yards and Terminals, Dr. Account No. 116—General Administration Joint Tracks, Yards and Terminals, Cr.: The proposed change from steam to electric operation will involve no apparent change in the expenditures chargeable to these accounts, and for the purposes of these estimates it has been assumed that the charges subsequent to electrification will be the same as those which now accrue for steam operation.

SUMMARY

301.06 Summary: A summary of the expense of steam operation and of the estimated expense of electric operation, by the 2,400-volt direct current and the 11,000-volt alternating current systems, is presented for each of the accounts which will be affected by the proposed change from steam to electric operation, by services, as table CDXIII.

The distribution of expenses among the four services recognized in this analysis is based upon the number of locomotive-miles performed in each service under steam operation within the terminals in the year 1912. The number of locomotive-miles performed in each service and the percentage of the total represented by each service are shown by table CDXIV.

A summary of the total expense for all services under affected accounts, for steam operation and for both 2,400-volt direct current and 11,000-volt alternating current operation, is presented as table CDXV.

Estimates have been made of the expense of the 600-volt direct current third rail operation on the Chicago & North Western Railway in the manner hereinbefore described in connection with the analyses of accounts. A summary, by accounts, of the expense of steam operation and the estimated expense of third rail direct current operation on the Chicago & North Western Railway, on the basis of the year 1912, is presented as table CDXVI.

A distribution of the total expense shown by table CDXVI among the four services recognized has been made on the basis of the number of locomotive-miles performed in each service under steam operation in the year 1912. The number of locomotive-miles performed in each service and the percentage of the total represented by each service are shown by table CDXVII.

The cost per locomotive-mile for steam operation and for 600-volt direct current operation, as indicated by dividing the total cost, under affected accounts, by the total number of locomotive-miles of service performed, is set forth by table CDXVIII.

The results presented in table CDXVIII indicate that the estimated saving in operating expense under the proposed 600-volt direct current third rail system on the Chicago & North Western Railway, as compared with the expense of steam operation, amounts to 12.74 cents per locomotive-mile, or to a total of $570,974 per annum, upon the basis of the 1912 service and conditions.

The total expense under affected accounts, of 600-volt direct current third rail operation on all roads within the proposed limits of electrification has been determined by applying to the expense, under the affected accounts, of steam operation in 1912 within the proposed limits of electrification the ratio between the estimated expense of 600-volt direct current third rail operation on the Chicago

TABLE CDXIII. SUMMARY OF ANNUAL OPERATING EXPENSE UNDER AFFECTED ACCOUNTS, FOR STEAM AND FOR ELECTRIC OPERATION, ALL ROADS

(Basis of 1912)

Account Number	Service	Steam		2,400-Volt D. C.		11,000-Volt A. C.	
		Total	Per Loco.-Mile, Cents	Total	Per Loco.-Mile, Cents	Total	Per Loco.-Mile, Cents
1	2	3	4	5	6	7	8
Maintenance of Way and Structure							
3 Ties	Through passenger	$102,919		$102,919		$102,919	
	Suburban passenger	81,011		81,011		81,011	
	Road freight	37,425		37,425		37,425	
	Yard and transfer	241,828		241,828		241,828	
Totals		463,183	1.911	463,183	1.911	463,183	1.911
6 Roadway and track	Through passenger	54,142		54,142		54,142	
	Suburban passenger	42,617		42,617		42,617	
	Road freight	19,688		19,688		19,688	
	Yard and transfer	127,216		127,216		127,216	
Totals		243,663	1.005	243,663	1.005	243,663	1.005
7 Removal of sand, snow and ice	Through passenger	53,492		53,492		53,492	
	Suburban passenger	42,105		42,105		42,105	
	Road freight	19,452		19,452		19,452	
	Yard and transfer	125,691		125,691		125,691	
Totals		240,740	0.993	240,740	0.993	240,740	0.993
11 Grade crossings, fences, guards, and signs	Through passenger	9,467		9,467		9,467	
	Suburban passenger	7,452		7,452		7,452	
	Road freight	3,443		3,443		3,443	
	Yard and transfer	22,246		22,246		22,246	
Totals		42,608	0.176	42,608	0.176	42,608	0.176
13 Signals and interlocking plants	Through passenger	90,105		95,788		95,559	
	Suburban passenger	70,924		75,398		75,217	
	Road freight	32,765		34,832		34,749	
	Yard and transfer	211,718		225,072		224,535	
Totals		405,512	1.673	431,090	1.778	430,060	1.774
14 Telegraph and telephone lines	Through passenger	8,859		9,863		9,863	
	Suburban passenger	6,971		7,762		7,762	
	Road freight	3,222		3,588		3,588	
	Yard and transfer	20,812		23,171		23,171	
Totals		39,864	0.164	44,384	0.183	44,384	0.183
15 Electric power transmission	Through passenger	0		221,729		219,247	
	Suburban passenger	0		174,529		172,576	
	Road freight	0		80,629		79,726	
	Yard and transfer	0		520,992		515,161	
Totals		0	0	997,879	4.116	986,710	4.070
16 Buildings, fixtures and grounds	Through passenger	30,912		142,791		142,791	
	Suburban passenger	24,331		112,395		112,395	
	Road freight	11,240		51,924		51,924	
	Yard and transfer	72,633		335,513		335,513	
Totals		$139,116	0.573	$642,623	2.651	$642,623	2.651

& North Western Railway and that of steam operation on the Chicago & North Western Railway as shown by the reports covering 1912. A summary showing the total unit expense, under affected accounts, for the operation of all roads within the proposed limits of electrification, for steam, for 600-volt, for 2,400-volt and for 11,000-volt operation, is presented as table CDXIX.

The estimated gain which may be expected to result from the introduction of electric operation within the proposed limits of electrification is shown, for each system, by table CDXX.

OPERATING EXPENSES INCIDENT TO THE PROPOSED NEW TRANSFER STATIONS

301.07 Number and Location of Transfer Stations: The proposed change from steam to electric operation will involve the establishment of facilities for the change of motive power, at the points on the several railroad lines which will mark the outer limits of electrification. At such points it will be necessary to establish transfer stations and steam locomotive terminals to provide for the care of certain steam locomotives which are now housed at terminals within the limits of electrification. These points will mark the termini of both steam and electric locomotive runs. All service beyond such transfer stations will be operated by steam and all service between the transfer stations and the terminals within the city of Chicago will be operated electrically.

Under the plan of electrification, as defined by roads (chapter 209), it will be necessary to establish 30 new transfer stations and 25 new establishments for the care of steam locomotives. Five existing establishments for the care of steam equipment are to be enlarged. The expense incident to the operation and maintenance of transfer stations will constitute an additional operating expense as a result of electrification, and that incident to the operation and maintenance of facilities for the care of steam equipment at transfer stations will effect changes in the present expense of steam operation. The effect

TABLE CDXIII (Continued). SUMMARY OF ANNUAL OPERATING EXPENSE UNDER AFFECTED ACCOUNTS, FOR STEAM AND FOR ELECTRIC OPERATION, ALL ROADS

(Basis of 1912)

Account Number	Service	Steam		2,400-Volt D. C.		11,000-Volt A. C.	
		Total	Per Loco.-Mile, Cents	Total	Per Loco.-Mile, Cents	Total	Per Loco.-Mile, Cents
1	2	3	4	5	6	7	8
Maintenance of Equipment							
25 and 28 Steam locomotives—repairs Electric locomotives—repairs	Through passenger	$ 351,504	6.525	$ 296,287	5.500	$ 296,287	5.500
	Suburban passenger	377,238	8.899	0	0	0	0
	Road freight	160,106	8.170	107,783	5.500	107,783	5.500
	Yard and transfer	857,547	6.776	632,782	5.000	632,782	5.000
Totals		1,746,395	7.204	1,036,852	5.184	1,036,852	5.184
31-A Multiple-unit trailer cars—repairs	Through passenger	0	....	0	....	0	....
	Suburban passenger	207,313	4.890	67,041	1.581	67,041	1.581
	Road freight	0	....	0	....	0	....
	Yard and transfer	0	....	0	....	0	....
Totals		207,313	4.890	67,041	1.581	67,041	1.581
31-B Multiple-unit motor cars—repairs	Through passenger	0	....	0	....	0	....
	Suburban passenger	0	....	168,909	3.985	167,515	3.952
	Road freight	0	....	0	....	0	....
	Yard and transfer	0	....	0	....	0	....
Totals		0	0	168,909	3.985	167,515	3.952
37 Electric equipment of multiple-unit motor cars—repairs	Through passenger	0	....	0	....	0	....
	Suburban passenger	0	....	106,439	2.511	106,439	2.511
	Road freight	0	....	0	....	0	....
	Yard and transfer	0	....	0	....	0	....
Totals		0	0	106,439	2.511	106,439	2.511
47-A and 86 Substations—operation and maintenance	Through passenger	0	....	14,310	0.266	2,786	0.052
	Suburban passenger	0	....	12,726	0.300	2,182	0.051
	Road freight	0	....	9,432	0.481	2,023	0.103
	Yard and transfer	0	....	53,532	0.423	10,059	0.083
Totals		0	0	90,000	0.371	17,050	0.070
47-B and 86 Power station—operation and maintenance	Through passenger	0	....	328,466	6.097	307,717	5.712
	Suburban passenger	0	....	292,108	6.891	241,032	5.686
	Road freight	0	....	216,499	11.048	223,443	11.402
	Yard and transfer	0	....	1,228,754	9.710	1,160,702	9.172
Totals		0	0	$2,065.827	8.522	$1,932,894	7.973

of all changes within the proposed limits of electrification has been considered in the analyses of accounts (section 301.05). It is the present purpose to consider the effect upon operating expenses of the operation and maintenance of all new facilities outside of the proposed limits of electrification.

301.08 Increased Cost of Handling Supplies: Under steam operation as conducted at present, the locomotive and train terminals are located usually in close proximity to each other, so that it is often possible for a single force to handle the supplies which are required for both locomotive and train operation. Under the proposed electric operation, the steam locomotive terminals will be located at the transfer points, while the train terminals will remain at established points within the limits of electrification. This change in operation will involve an increased labor charge for handling supplies such as lanterns, oil, waste and

TABLE CDXIII (Concluded). SUMMARY OF ANNUAL OPERATING EXPENSE UNDER AFFECTED ACCOUNTS, FOR STEAM AND FOR ELECTRIC OPERATION, ALL ROADS

(Basis of 1912)

Account Number	Service	Steam		2,400-Volt D. C.		11,000-Volt A. C.	
		Total	Per Loco.-Mile Cents	Total	Per Loco.-Mile, Cents	Total	Per Loco.-Mile, Cents
1	2	3	4	5	6	7	8
Transportation Expenses							
68 Yard conductors and brakemen...........	Through passenger....................	0	....	0	....	0	....
	Suburban passenger....................	$ 53,636	1.265	$ 26,818	0.633	$ 26,818	0.633
	Road freight..........................	0	....	0	....	0	....
	Yard and transfer.....................	0	....	0	....	0	....
Totals............................	....	53,636	1.265	26,818	0.633	26,818	0.633
71 Yard enginemen.........................	Through passenger....................	0	....	0	....	0	....
	Suburban passenger....................	42,539	1.003	21,270	0.502	21,270	0.502
	Road freight..........................	0	....	0	....	0	....
	Yard and transfer.....................	0	....	0	....	0	....
Totals............................	....	42,539	1.003	21,270	0.502	21,270	0.502
72 Engine house expense—yard	Through passenger..	0	....	0	....	0	....
	Suburban passenger..	63,348	1.494	6,335	0.149	6,335	0.149
	Road freight..........................	0	....	0	....	0	....
	Yard and transfer..	570,134	4.505	120,361	0.951	120,361	0.951
Totals............................	....	633,482	3.750	126,696	0.750	126,696	0.750
73 Fuel for yard locomotives................	Through passenger....................	0	....	0	....	0	....
	Suburban passenger....................	407,698	9.618	0	....	0	....
	Road freight..........................	0	....	0	....	0	....
	Yard and transfer.....................	3,669,280	28.993	0	....	0	....
Totals............................	....	4,076,978	24.132	0	0.	0	0
74 Water for yard locomotives...............	Through passenger....................	0	....	0	....	0	....
	Suburban passenger....................	13,704	0.323	0	....	0	....
	Road freight..........................	0	....	0	....	0	....
	Yard and transfer.....	123,340	0.975	0	....	0	....
Totals............................	....	137,044	0.811	0	0	0	0
79 and 80 Motormen................................. Road enginemen........................	Through passenger....................	0	....	0	....	0	....
	Suburban passenger....................	362,020	8.540	198,178	4.675	198,178	4.675
	Road freight..........................	0	....	0	....	0	....
	Yard and transfer.....................	0	....	0	....	0	....
Totals............................	....	362,020	8.540	198,178	4 675	198,178	4 675
81 Engine house expense—road	Through passenger....................	258,039	4.790	51,608	0.958	51,608	0 958
	Suburban passenger....................	263,715	6.221	52,742	1.244	52,742	1 244
	Road freight..........................	138,158	7.050	27,632	1.410	27,632	1 410
	Yard and transfer.....................	0	....	0	....	0	....
Totals............................	....	659,912	5.696	131,982	1.139	131,982	1.139
82 Fuel for road locomotives................	Through passenger....................	419,771	7.792	0	....	0	....
	Suburban passenger....................	334,317	7.886	0	....	0	....
	Road freight..........................	452,090	23 070	0	....	0	....
	Yard and transfer.....................	0	....	0	....	0	....
Totals............................	....	1,206,178	10.411	0	0	0	0
83 Water for road locomotives...............	Through passenger....................	54,172	....	0	....	0	....
	Suburban passenger	42,629	....	0	....	0	....
	Road freight..........................	19,707	....	0	....	0	....
	Yard and transfer.....................	0	....	0	....	0	....
Totals............................	....	116,508	1.006	0	0	0	0
94 Telephone and telegraph operation........	Through passenger....................	26,083	....	46,576	....	47,509	....
	Suburban passenger....................	20,525	....	36,651	....	37,385	....
	Road freight..........................	9,488	....	16,943	....	17,283	....
	Yard and transfer.....................	61,277	....	109,419	....	111,612	....
Totals............................	....	$117,373	0.484	$209,589	0 865	$213,789	0 882

TABLE CDXIV. LOCOMOTIVE-MILES PERFORMED IN EACH SERVICE WITHIN THE LIMITS OF ELECTRIFICATION UNDER STEAM OPERATION IN 1912, ALL ROADS

Service	Loco.-Miles for 1912	Per Cent of Total
Through passenger	5,387,035	22.22
Suburban passenger	4,239,110	17.49
Road freight	1,959,685	8.08
Yard and transfer	12,655,645	52.21
Totals	24,241,475	100 00

TABLE CDXV. SUMMARY OF ANNUAL OPERATING EXPENSE UNDER AFFECTED ACCOUNTS, FOR STEAM AND FOR ELECTRIC OPERATION

(Basis of 1912)

Acct. No.	Item	Steam	2,400-Volt D. C.	11,000-Volt A. C.
1	2	3	4	5
3	Ties	$ 463,183	$ 463,183	$ 463,183
6	Roadway and track	243,663	243,663	243,663
7	Removal of sand, snow and ice	240,740	230,740	240,740
11	Grade crossings, fences, cattle-guards and signs	42,608	42,608	42,608
13	Signals and interlocking plants	405,512	431,090	430,060
14	Telegraph and telephone lines	39,864	44,384	44,384
15	Electric power transmission	0	997,879	986,710
16	Buildings, fixtures and grounds	139,116	642,623	642,623
25 and 28	Steam and electric locomotive -repairs	1,746,395	1,036,852	1,036,852
31-A	Passenger train trailer cars—repairs	207,313	67,041	67,041
31-B	Multiple-unit motor cars—repairs	0	168,909	167,515
37	Electric equipment of motor cars—repairs	0	106,439	106,439
47-A and 86	Substations—operation and maintenance of equipment	0	90,000	17,050
47-B and 86	Power station—operation and maintenance of equipment	0	2,065,827	1,932,894
68	Yard conductors and brakemen	53,636	26,818	26,818
71	Yard enginemen	42,539	21,270	21,270
72	Engine house expense—yard	633,482	126,696	126,696
73	Fuel for yard locomotives	4,076,978	0	0
74	Water for yard locomotives	137,044	0	0
79 and 80	Road enginemen (steam) and motormen (electric) in suburban passenger service	362,020	198,178	198,178
81	Engine house expense—road	659,912	131,982	131,982
82	Fuel for road locomotives	1,206,178	0	0
83	Water for road locomotives	116,508	0	0
94	Telegraph and telephone operation	117,373	209,589	213,789
	Totals	$10,934,064	$7,355,771	$7,140,495

signals, and in many cases will also require an increased investment in such supplies. At the terminals within the limits of electrification, it will be necessary after electrification to continue to maintain supply depots for trains, and electric locomotives and multiple-unit equipment, and it will be necessary in most cases to retain the present force for the handling of such supplies. The force needed at the outside terminal to handle steam locomotive supplies will therefore be additional. It is estimated that the work of handling supplies at the transfer stations will require two men, one for day service and one for night service. The combined salaries of these two men are estimated at $140 per month. It is assumed for purposes of these estimates that these men may also be assigned certain other duties, so that all of their time will not be directly chargeable to the handling of supplies.

TABLE CDXVI. SUMMARY OF ANNUAL OPERATING EXPENSES UNDER AFFECTED ACCOUNTS, FOR STEAM AND FOR ELECTRIC OPERATION ON THE CHICAGO & NORTH WESTERN RAILWAY

(Basis of 1912)

Account No.	Item	Steam	600-Volt D. C.
1	2	3	4
3	Ties	$ 71,649	$ 74,092
6	Roadway and track	37,691	43,346
7	Removal of sand, snow and ice	84,186	86,846
11	Grade crossings, fences, cattle-guards and signs	2,278	5,282
13	Signals and interlocking plants	117,651	123,015
14	Telegraph and telephone lines	2,634	3,370
15	Electric power transmission	0	193,600
16	Buildings, fixtures and grounds	22,056	128,720
25 and 28	Steam and electric locomotive-repairs	308,615	163,172
31-A	Passenger train trailer cars—repairs	61,418	16,105
31-B	Multiple-unit motor cars—repairs	0	57,217
37	Electric equipment of motor cars—repairs	0	30,551
47-A and 86	Substations—operation and maintenance of equipment	0	103,600
47-B and 86	Power station—operation and maintenance of equipment	0	398,904
68	Yard conductors and brakemen	19,087	9,543
71	Yard enginemen	10,009	5,004
72	Engine house expense—yard	99,417	19,883
73	Fuel for yard locomotives	534,852	0
74	Water for yard locomotives	28,633	0
79 and 80	Road enginemen (steam) and motormen (electric) in suburban passenger service	78,210	56,959
81	Engine house expense—road	216,230	43,246
82	Fuel for road locomotives	432,058	0
83	Water for road locomotives	23,983	0
94	Telegraph and telephone operation	4,460	24,088
	Totals	$2,158,117	$1,587,143

TABLE CDXVII. LOCOMOTIVE-MILES PERFORMED IN EACH SERVICE WITHIN THE LIMITS OF ELECTRIFICATION UNDER STEAM OPERATION ON THE CHICAGO & NORTH WESTERN RAILWAY

(Basis of 1912)

Service	Loco.-Miles for 1912	Per Cent of Total
Through passenger	1,157,415	25.82
Suburban passenger	1,218,370	27 18
Road freight	293,825	6.56
Yard and transfer	1,812,199	40 44
Totals	4,481,809	100 00

TABLE CDXVIII. TOTAL AND UNIT COSTS, UNDER AFFECTED ACCOUNTS, OF STEAM OPERATION AND OF 600-VOLT D. C. OPERATION ON THE CHICAGO & NORTH WESTERN RAILWAY

(Basis of 1912)

Service	Loco.-Miles	Steam		600-Volt D. C.	
		Total	Per Loco.-Mile Cents	Total	Per Loco.-Mile Cents
1	2	3	4	5	6
Through passenger	1,157,415	$411,575	35.560	$363,472	31 404
Suburban passenger	1,218,370	731,906	60.072	502,152	41.215
Road freight	293,825	179,144	60.970	112,864	38.412
Yard and transfer	1,812,199	835,492	46.103	608,655	33.587
Totals	4,481,809	$2,158,117	48.153	$1,587,143	35.413

A careful study has been made of all factors entering into this problem, and it is estimated that an increase of 50 per cent in the present expense of handling supplies will result from the changes incident to electrification. Upon the basis indicated, the increased operating expense of handling supplies, resulting from the proposed changes for all roads affected, will amount to $30,000 per annum.

TABLE CDXIX. SUMMARY OF TOTAL AND AVERAGE UNIT EXPENSE, UNDER AFFECTED ACCOUNTS, FOR STEAM AND FOR ELECTRIC OPERATION OF ALL ROADS WITHIN THE PROPOSED LIMITS OF ELECTRIFICATION

(Basis of 1912)

Service	Locomotive-Miles	Steam		600-Volt D. C.		2,400-Volt D. C.		11,000-Volt A. C	
		Total	Per Loco.-Mile, Cents	Total	Per Loco.-Mile, Cents	Total	Per Loco.-Mile, Cents	Total	Per Loco.-Mile, Cents
1	2	3	4	5	6	7	8	9	10
Through passenger	5,387,035	$1,459,460	27.092	....	.....	$1,427,432	26.498	$1,393,381	25.865
Road freight	1,959,685	906,779	46.272	....	.....	629,260	32.110	628,148	32.054
Suburban passenger	4,239,110	2,464,098	58.128	....	.....	1,532,493	36.151	1,468,080	34.632
Yard and transfer	12,655,645	6,103,727	48.229	....	.....	3,766,586	29.762	3,650,886	28.848
Totals	24,241,475	$10,934,064	45.104	$8,442,298	34.826	$7,355,771	30.344	$7,140,495	29.456

TABLE CDXX. ESTIMATED REDUCTION IN OPERATING EXPENSES DUE TO ELECTRIFICATION*

(Based on the Service of 1912)

System of Operation (All Services)	Number of Locomotive-Miles per Annum	Expense Under Affected Accounts		Gain Due to Electrification	
		Per Loco.-Mile, Cents	Total Expense per Annum	Per Loco.-Mile, Cents	Total Expense per Annum
1	2	3	4	5	6
Steam	24,241,475	45.104	$10,934,064	.....	.....
600-volt direct current third rail	24,211,475	34.826	8,442,298	10.278	$2,491,766
2,400-volt direct current overhead	24,241,475	30.344	7,355,771	14.760	3,578,293
11,000-volt alternating current overhead	24,241,475	29.456	7,140,495	15.648	3,793,569

*Attention is called to the fact that the gain shown in this table as being due to electrification relates only to operation within the proposed limits of electrification. It will be materially reduced by the added expense of operation beyond the limits of electrification (section 305.15), which added expense is necessary to permit of the continuous operation of the roads having terminals only electrified.

301.09 Labor and Materials at Transfer Points for Handling Locomotives, Supplying Water, Inspecting Trains and Changing Motive Power: Under the plan of operation which must follow the electrification of Chicago's railroad terminals, it will be necessary to stop all through trains at the points which mark the limits of electric operation to change motive power. This change of motive power will require the uncoupling and coupling of the locomotives, the inspection and test of brakes, and other operations which will necessitate the presence of several attendants at each transfer yard. A force will also be required at the roundhouse to handle steam locomotives.

To test brakes promptly and properly, inspect trains and assist in coupling and uncoupling locomotives, a force of three men on duty constantly will be required. At the rates now paid this class of labor, one of these men will receive $0.25 per hour and two will receive $0.225 per hour each, the total amounting to $0.70 per hour. This item of expense will therefore amount to $16.80 per transfer station per day or to $6,132 per transfer station per annum. A careful study of operating conditions indicates that the force which will be required at 13 of the proposed new transfer stations may be transferred from other points and will therefore not constitute an additional expense. For the remaining 17 new transfer stations a new force will be necessary. On the basis of an annual expense of $6,132 per station, the total annual additional expense incident to this item for all roads will amount to $104,244.

The cost of handling steam locomotives operating in through passenger and road freight services within the proposed limits of electrification, as indicated by reports furnished by the railroads, amounted in 1912 to $659,912 (section 301.05). This amount includes the cost of labor and of materials required in cleaning fires, inspecting and cleaning locomotives, washing boilers, kindling fires and preparing steam locomotives for service. The cost of water furnished to steam locomotives in these two services during 1912, within the proposed limits of electrification, amounted to $116,508 (section 301.05). Assuming that the expense of performing this service for through passenger and road freight locomotives at the outside steam locomotive terminals will be the same as that at the present terminals within the proposed limits of electrification, the additional expense which will be incurred subsequent to electrification in the operation of steam service outside of the proposed limits of electrification will amount to $776,420 per annum.

Under present steam operation there are certain steam locomotives operating in yard and transfer services which are housed and watered at points within the proposed limits of electrification but which perform service outside of these limits. In the consideration of expenses within the proposed limits of electrification (section 301.05), this item of expense has been eliminated. Subsequent to electrification, however, these steam locomotives will be housed at convenient points outside of the electric limits, and the expense of housing and watering them will constitute an additional expense which will be incurred in steam operation outside of the proposed limits. A study of the operation of yard and transfer services indicates that in 1912 there were 83 steam yard and transfer locomotives which performed service outside of the electric limits and were cared for at points within these limits. In 1912 the steam engine house expense incident to yard and transfer locomotives within the proposed limits of electrification amounted to $842.39 per locomotive per annum for handling and $182.24 per locomotive per annum for water. On this basis the expense per annum for handling and watering these 83 locomotives will amount to $85,044. There will be the additional expense of maintaining the new trackage, and the contact system and bonding of that part of the new trackage which will be electrified. This added expense has not been included in any of the primary accounts for operation within the limits of electrification. The estimated added expense due to this factor is shown by the following:

Total miles of new track	338
Annual expense of maintaining new tracks, 5 per cent of the estimated cost per mile for materials, or $350	$118,300
Annual cost of maintaining contact system and bonding 149.4 miles, electrified, at $285 per mile, for the 2,400-volt direct current system	42,579
Total additional annual maintenance expense .	$160,879

A summary of the total additional annual expense of labor and materials at transfer points for handling steam locomotives, supplying water, inspecting trains and changing motive power is presented as follows:

	PER ANNUM
Labor for inspecting trains and changing motive power	$104,244
Handling locomotives in through passenger and road freight services	659,912
Water for locomotives in through passenger and road freight services	116,508
Engine house expenses incident to yard and transfer locomotives	85,044
Maintenance of new tracks, contact system and bonding	160,879
Total	$1,126,587

Some increased expense will arise from the necessity of carrying a larger stock of supplies and materials to cover the requirements of the new transfer stations. It is difficult to estimate the amount of such expense, and for purposes of these estimates no allowance has been made to cover this item.

301.10 Expenses of Telegraph and Telephone Operation at the Transfer Stations: A force of three telegraph and telephone operators will be required at each of 17 new transfer stations. The average salary of an operator is estimated at $75.00 per month. The additional expense due to this new force will, therefore, amount to $45,900 per annum for all roads.

301.11 Delay and Damage Incident to Stops at Transfer Stations: Under electric operation it will be necessary to stop all through passenger and road freight trains at the proposed transfer stations. Such stops are not necessary under steam operation, and the introduction of them will result in certain delays and damage to equipment which will involve an added operating expense.

There is no known method by which it is possible definitely to estimate the cost of stopping a train, changing locomotives, testing brakes and setting the train in motion again. Those who have studied the problem agree that a significant element of expense exists, due to:

1. Loss of time resulting in certain instances in overtime for train crews.
2. Damage to equipment.
3. Extra fuel required to start a train.

A discussion of these factors with a number of railroad officials brought forth different views upon the subject and varying estimates of the probable expense of items involved. A careful study of all such estimates has been made and, for the purposes of this study, the unit additional operating expense incident to damage and delay in making the extra stops at transfer points has been fixed as follows:

	PER STOP
Passenger trains	$0.45
Freight trains	1.28

These units are in close agreement with the averages of the various estimates made by railroad officials. In 1912 there were, on the average, 704 passenger trains and 488 freight trains either entering or leaving Chicago daily, which would, with electric operation, be required to stop at transfer stations. On this basis, therefore, the additional annual expense due to this factor will amount to $115,632 for passenger trains and $227,994 for freight trains, or a total of $343,626.

301.12 Summary: The additional operating expenses per annum incident to the new transfer stations required, so far as it has been practicable to estimate them, are, on the basis of the service requirements of 1912, as follows:

	PER ANNUM
Increased cost of handling supplies	$ 30,000
Handling locomotives, supplying water, inspecting trains and exchanging motive power, and maintaining tracks, contact system and bonding . .	1,126,587
Telegraph and telephone operation at transfer stations	45,900
Delay and damage incident to stops at transfer stations	343,626
Total	$1,546,113

EFFECT OF ELECTRIFICATION ON OPERATING EXPENSES RESULTING FROM THE SHORTENING OF STEAM OPERATED DIVISIONS

301.13 The Effect of Electrification upon the Length of Existing Railroad Divisions: All the lines of through railroad routes are subdivided into operating divisions. Each division is, in many respects, an operating unit. Locomotives and locomotive crews belonging to one division do not, in the ordinary routine of operation, appear in the activities of other divisions. The length of divisions is determined generally with reference to conditions affecting operation; that is, they are as long as can be effectively operated. Any arbitrary change in the length of an operating division will necessitate changes in the manner in which operation proceeds, and generally such changes will introduce changes in the expense of conducting operation.

The electrification of the railroad terminals of Chicago will have the effect of dividing existing steam operated divisions into two parts; it will make two operating divisions where at present a single division suffices. Those portions of the present steam operated divisions which lie within the city of Chicago and its immediate vicinity will constitute electrically operated divisions. The remaining portions will continue as steam operated divisions. The effect upon the operating expenses of the electrified division is set forth in the preceding analyses of expenses by accounts. It is the present purpose to consider the manner and extent to which the arbitrary shortening of the steam operated divisions of the several roads will affect the expense of the steam operation which must continue subsequent to electrification.

301.14 Details of the Changes as Affecting Individual Roads: Under the present conditions of steam operation, the average distance between the Chicago terminals and the first division point outside of Chicago is 136 miles. This distance between division terminals will be shortened, on the average, by approximately ten miles as a result of electrification. The extent to which the proposed changes will affect individual roads is shown by table CDXXI, in which are given the present length of the divisions terminating in Chicago of 14 of the principal roads and the length of the steam operated divisions of these roads as they will exist after the electrification of the Chicago terminals.

The distances given in table CDXXI are based upon the present and proposed runs of through passenger and road freight locomotives in all cases except that of the Chicago, Rock Island & Pacific Railway. On this road Joliet, Ill., is at present a terminal point for eight daily passenger trains which are handled by four different locomotives. Each of these locomotives is at present used to protect two suburban passenger schedules between La Salle Station and Burr Oak before being needed for the Joliet return schedule.

It will be noted that some roads are affected by the proposed change to a greater degree than others. Several roads having a number of so-called local passenger trains, which have their origin or destination at points between the regularly established locomotive terminals or division points applying to their through passenger and road freight services, will be materially affected by the shortening of the steam locomotive run. These local trains cover a distance of less than 100 miles, but the schedules are so arranged that the crews operating the trains may protect two schedules and in this way avoid short mileage for a day's work. Any plan, however, under which these locomotives will be cut off at the point which marks the outer limits of electrification, must necessarily reduce the length of run for such locomotives to a point below the limit of 100 miles.

301.15 Additional Constructive Mileage to Steam Locomotive Crews Due to Shortening of the Steam Operated Divisions: The fact has already been noted that, under present labor agreements, the minimum day's work for locomotive crews is 100 miles, or 10 consecutive hours of service, and payment must be made for this minimum day whether the service is performed or not. Consequently, any reduction in the length of the run of a locomotive will result in loss to the railroad whenever the distance traveled is less than 100 miles and schedules cannot be readjusted to permit individual train crews to protect another run within 10 hours from the time the initial trip was begun.

The manner in which the shortening of runs under the proposed plan of electric operation will result in increased operating expenses to many of the railroads affected is shown by the following example. One of Chicago's railroads now operates locomotives in road freight service between a freight terminal in Chicago and a point 94 miles distant. The average speed of road freight trains while in service, from start to final stop, is 9.4 miles per hour. The average time required to make this trip is, therefore, 10 hours, for which the crew is paid on the basis of 100 miles. If the distance run were actually 100 miles and the time consumed 10 hours, the crew would be paid the same as they are now paid for 94 miles. This railroad now pays each road freight crew for 6 constructive miles, that is, for 6 miles more than are actually run. This represents a loss over minimum labor costs of 6 per cent. Under electrification the division for steam operation will be shortened to 71 miles and the run will require an average of 7.6 hours. This will leave only 2.4 hours in which to start the crew again on another run. This can be accomplished in so few instances that the possibility of overcoming the loss is remote. The loss due to this factor will, therefore, be 29 miles instead of 6 miles as at present. The rate of loss represented by the combined pay of the engineer and fireman will, in this instance, be $.095 per mile or $2.755 per train. The road in question operates an average of 25 road freight trains daily, so that the loss per day on the operation of road freight trains will be $68.88 and the loss per year $25,141. In

TABLE CDXXI. PRESENT LENGTH OF RAILROAD DIVISIONS TERMINATING IN CHICAGO AND LENGTH OF STEAM OPERATED DIVISIONS AFTER THE PROPOSED ELECTRIFICATION OF THE CHICAGO TERMINALS

(Basis of 1912)

Railroad	Service	Present Terminals			Proposed Terminals			Decrease Miles
		From	To	Miles	From	To	Miles	
1	2	3	4	5	6	7	8	9
Atchison, Topeka & Santa Fe Ry.	Pass.	Dearborn Station	Chillicothe	130	McCook	Chillicothe	117	13
Atchison, Topeka & Santa Fe Ry.	Frt.	18th St.	Chillicothe	128	McCook	Chillicothe	117	11
Baltimore & Ohio R. R.	Pass.	Grand Central Station	Garrett	150	Pine Junction	Garrett	122	28
Baltimore & Ohio R. R.	Frt.	So. Chicago	Garrett	131	Pine Junction	Garrett	122	9
Chesapeake & Ohio Ry. of Indiana	Pass.	Dearborn Station	Peru	123	HY Tower	Peru	100	23
Chicago & Alton R. R.	Pass.	Union Depot	Bloomington	127	Glenn	Bloomington	116	11
Chicago & Alton R. R.	Frt.	Brighton Park	Bloomington	121	Glenn	Bloomington	116	5
Chicago & Eastern Illinois R. R.	Pass.	Dearborn Station	Danville	123	Yard Center	Danville	105	18
Chicago & North Western Ry., Milwaukee Division	Pass.	Chicago Terminal	Milwaukee	85	Waukegan	Milwaukee	49	36
Chicago & North Western Ry., Milwaukee Division	Frt.	40th Ave. Yard	Milwaukee	87	Waukegan	Milwaukee	49	38
Chicago & North Western Ry., Wisconsin Division	Pass.	Chicago Terminal	Elroy	204	Desplaines	Elroy	187	17
Chicago & North Western Ry., Galena Division	Pass.	Chicago Terminal	Clinton	138	Proviso	Clinton	125	13
Chicago, Burlington & Quincy R. R	Pass.	Union Depot	Galesburg	163	Hawthorne	Galesburg	156	7
Chicago, Indianapolis & Louisville Ry	Pass.	Dearborn Station	Shop yards	118	So. Hammond	Shop yards	95	23
Chicago, Milwaukee & St. Paul Ry	Pass.	Union Depot	Milwaukee	85	Morton Grove	Milwaukee	70	15
Chicago, Rock Island & Pacific Ry	Pass.	La Salle Station	Joliet	40	Burr Oak	Joliet	24	16
Lake Shore & Michigan Southern Ry	Pass.	La Salle Station	Elkhart	100	Millers	Elkhart	71	29
Lake Shore & Michigan Southern Ry	Frt.	Englewood	Elkhart	94	Millers	Elkhart	71	23
Michigan Central R. R.	Pass.	Central Station	Niles	93	Gibson	Niles	70	23
Michigan Central R. R.	Frt.	Kensington	Niles	80	Gibson	Niles	70	10
Pittsburgh, Cincinnati, Chicago & St. Louis Ry	Pass.	Union Depot	Logansport	118	Bernice	Logansport	91	27
Wabash R. R., Decatur Division	Pass.	Dearborn Station	Forrest	93	Chicago Ridge	Forrest	77	16

through passenger service the rate of loss is \$.075 per mile and in the case of this road the loss will be 29 miles, or \$2.175 per train. Thirty-eight passenger trains are operated daily and the loss in passenger service will therefore be \$82.65 per day, or \$30,167 per year. The total loss due to shortening of runs in the case of this road will amount to \$55,308 per year.

The schedules and operating conditions on each railroad have been carefully studied in a manner similar to that which is illustrated in the foregoing example. In the case of some roads it has been feasible to base the estimates upon the possibility of doubling the number of runs or protecting additional schedules in other ways with a single crew. All schedules have been studied in order that due allowance might be given to all such possible arrangements. On the basis described, the estimated annual expense which will be added for the operation of the steam operated divisions, due to the shortening of these divisions as a result of the introduction of electric operation, will be \$450,000.

SUMMARY OF THE EFFECTS OF ELECTRIFICATION UPON OPERATING EXPENSES

301.16 Estimate of the Net Operating Result of Electrification, on the Basis of 1912: As set forth in the preceding sections, it has been shown that the introduction of electric operation in Chicago's railroad terminals will result in changes in operating expenses which will become apparent in three ways, as follows:

1. It will reduce the expense of railroad operation within the proposed limits of electrification.
2. It will result in the addition of certain factors of expense incident to the operation of the proposed new transfer stations.
3. It will increase the expense of steam operation of divisions immediately outside the proposed limits of electrification.

The net effect of these changes is different for each of the three systems of electric traction for which estimates have been prepared. All estimates have been based upon the assumption that the railroads will operate jointly such facilities as the power station, substations and transmission lines, and that they will, to some extent, use jointly such equipment as patrol trains, work and inspection trains and, in the case of the third rail system, special cars for removing snow and ice. On this basis the net effect upon operating expenses of the introduction of each of the three systems of electric traction may be summarized as shown by table CDXXII.

As has been stated, these estimates do not take into consideration the effect of electrification upon the charges incident to depreciation of structures

TABLE CDXXIII. ESTIMATED NET OPERATING RESULT OF ELECTRIFICATION OF CHICAGO'S RAILROAD TERMINALS, ALL ROADS*

(Basis of 1922)

All Services			
System of Traction	Expense under Affected Accounts for Operation within the Proposed Limits of Electrification	Increase in Operating Expenses Due to the New Transfer Stations and to the Reduced Length of Steam Operated Divisions Immediately beyond the Limits of Electrification	Net Decrease as Compared with the Cost of Steam Operation
1	2	3	4
Steam	\$14,214,283	....	....
11,000-volt A. C. overhead	9,282,644	\$2,594,947	\$2,336,693
2,400-volt D. C. overhead	9,562,502	2,594,947	2,056,834
600-volt D. C. third rail	10,974,987	2,594,947	644,349

* The determinations of the Committee as summarized by the values set forth in this table do not provide a basis upon which the percentage of saving in operating expenses due to electrification may be ascertained. The items considered in this report include only those which will be affected by the proposed change from steam to electric operation. The total expense either for steam or for electric operation has not been determined.

TABLE CDXXII. ESTIMATED NET OPERATING RESULT OF ELECTRIFICATION OF CHICAGO'S RAILROAD TERMINALS, ALL ROADS

(Basis of 1912)

All Services						
System of Traction	Total Number of Locomotive-Miles per Annum 1912	Expense under Affected Accounts for Operation within the Proposed Limits of Electrification		Expenses Incident to the Operation of New Transfer Stations	Additional Expense of Operating Steam Divisions Immediately beyond the Limits of Electrification	Estimated Net Decrease in Operating Expenses which will Result from the Introduction of Electric Operation
		Cents per Loco.-Mile	Total Expense* per Annum			
1	2	3	4	5	6	7
Steam	24,241,475	45.104	\$10,934,064	....	....	....
11,000-volt alternating current overhead	24,241,475	29.456	7,140,495	\$1,546,113	\$450,000	\$1,797,456
2,400-volt direct current overhead	24,241,475	30 344	7,355,771	1,546,113	450,000	1,582,180
600-volt direct current third rail	24,241,475	34 826	8,442,298	1,546,113	450,000	495,653

* See note under table CDXXIII.

and equipment nor upon those incident to interest on the investment required. These factors are elsewhere considered (chapter 401).

301.17 Estimate of the Net Operating Result of Electrification, on the Basis of 1922: The estimates of the net effect of the electrification of Chicago's railroad terminals upon operating expenses have been extended in a manner normal to these estimates (section 212.09), the factor of extension in this case being, to cover growth from 1912 to 1922, 30 per cent. On this basis the estimated net operating results which may be expected upon completion of the electric installation in 1922 are as set forth in table CDXXIII.

302. RESULTS TO BE ANTICIPATED FROM ELECTRIFICATION, THE VALUE OF WHICH IS INDETERMINATE

SYNOPSIS: The electrification of Chicago's railroad terminals will bring about certain changes, the money value of which is indeterminate. Some of these will appear in the nature of direct benefits to the railroads; others will make possible supplemental procedures of a profitable character; and still others may prove detrimental to the interests of the railroads. This chapter presents a discussion of these indeterminate results.

302.01 Character of Indeterminate Results: In the preceding chapter have been presented a discussion and analysis of the operating results to be anticipated from electrification as effecting a reduction in the expense of operation. In addition to these economies other effects of importance will appear. Some of these are obviously in the nature of benefits and, although their definite money value cannot be ascertained, a consideration of them must be included in any estimate of the return which is to be derived from electrification. Other effects will appear which may or may not be beneficial to the interests of the railroads, and still others which may be beneficial only in so far as they may permit supplemental procedures of a profitable character. To the more important of these indeterminate results, whether beneficial or otherwise, attention is given in the sections which follow.

302.02 Increased Capacity of the Terminals: Electric operation of the railroad terminals of Chicago, when compared with steam operation, will permit some increase in capacity due to the greater celerity with which the movement of trains may proceed. This being the case, there may be more movements over a given trackage per unit of time, with a resulting increase in the capacity of tracks and terminal stations.

In the designs of electric locomotives which underlie estimates of cost, an effort has been made to secure power units which will be capable of performing the service now performed by steam locomotives. A precautionary margin of five per cent has been allowed as a factor of safety, the assumption being that the electric equipment thus provided will perform all service now performed by the steam locomotive. But even under this assumption the electric locomotive has some advantage over the steam locomotive in starting and in accelerating trains. The power resources behind the electric locomotive are practically unlimited and permit the utilization of the maximum tractive effort of the locomotive throughout the start, with the result that acceleration takes place in less time than is now required with steam. This, where speed restrictions permit, will tend to increase slightly the capacity of a terminal station by lessening the amount of time required to move trains out through the throat of the yard. Similarly, in yard service, while the maximum speed must be limited and while conditions of operation require the observance of a certain order of movements, the fact that each movement as it occurs can be attended by a higher rate of acceleration will contribute some increase in the rate at which the work may be accomplished.

The electric locomotive is more effective than the steam locomotive in meeting the requirements of uninterrupted service. The attention required by the electric locomotive is limited to brief inspection periods, which occur at comparatively infrequent intervals. The electric locomotive wastes no time in taking on coal or water: it has no fires to be renewed, and no ash-pans to be cleaned. Hence the time during which it occupies trackage without performing productive service is materially reduced as compared with that required by the steam locomotive. Normally, the electric locomotive has no dead mileage to make, it is always ready for service, it is never "short of steam" and in winter it is not delayed by weather conditions. This increased efficiency cannot but operate favorably in increasing both the capacity of existing tracks and the serviceability of existing equipment in all branches of the operating service.

The preceding statements apply to the movement of cars by locomotives. While electrification will, as stated, increase efficiency in the movement of locomotive drawn trains, it is through the introduction of multiple-unit equipment in suburban passenger service that electric traction will make its greatest contribution to increased capacity of terminals. This is due to three facts:

> 1. Multiple-unit trains are higher powered than are trains drawn by locomotives; the motors are applied to a greater number of wheels, and the resulting rate of acceleration of a motor car train is much higher than that of a train hauled by a locomotive, whether steam or electric. This difference gives the multiple-unit train a material advantage over a steam operated train, regardless of the character of the track it may chance to occupy.
>
> 2. In terminal stations the idle car movements in and out are reduced in number. Thus, in multiple-unit service, some of the trains arriving at the terminal station may at once be reloaded for departure. Even if the arriving train is to be switched to the yard, no locomotive is required, the train moving at once to its designated place by means of its own power. The simplicity of such operations compared with those that must be performed where trains of cars are made up, in and out of stations, by steam locomotives is at once apparent.*
>
> 3. The more perfect control under which multiple-unit trains may proceed permits their operation on the road with less headway than trains drawn by locomotives.†

These effects serve to increase the capacity of trackage and the service to be obtained from equipment using it. They are susceptible of either one of two interpretations:

> 1. In locations where operation under present conditions is congested, the increase in capacity gives relief and affords opportunities for improvements in service, a result which has a distinct and immediate value; or,
>
> 2. In locations where at present there is no congestion of traffic, the increase in capacity constitutes in effect an enlargement of existing facilities and by so doing postpones the day when additional facilities will need to be provided. In this case the benefit in its effect on terminal capacity is remote.

It may be concluded from the preceding discussion that the extent to which electrification will increase the capacity of terminal tracks and stations will depend upon many conditions. It will doubtless be measurable in all branches of the service, but it will be most significant in its effect upon that portion of the total service, now performed by steam, which under electrification can be performed by multiple-unit equipment.

302.03 Reliability of Electric Service: Experience has shown that delays arising from derangements or deficiencies of motive power occur less frequently in connection with electric operation than with steam operation. Data relating to the electric operation of the New York, New Haven & Hartford Railroad* indicate that the number of locomotive failures under electric operation is 9 per 100,000 locomotive-miles, while under steam operation the number of such failures is 21 per 100,000 locomotive-miles. On this basis, the number of failures under steam operation is 2⅓ times as great as under electric operation. It is further reported of this road that "the high record of 1910 shows 91 per cent of its trains on time with an average delay of 1.5 minutes. A large portion of the train service of this line is, of course, the suburban service into New York, which is handled electrically, and the above record indicates the reliability of that service. The same favorable result is shown by the electrically operated suburban trains on the New York Central."† Experience on the Long Island Railroad, which, it will be remembered, presents a network of track carrying multiple-unit equipment, shows that, "relative to regularity and reliability, in five years there has been but one serious delay to the electric operation on Long Island, which was due entirely to something over which we have no control, and the same sort of an accident might have crippled steam service."‡

In the month of November, 1909, the electric locomotives of the New Haven road are reported to have run 22,000 miles for each minute's delay, and it is also reported that 5,000 train-miles a day were frequently run without a second's delay.¶

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[*] The Pennsylvania Railroad has entered upon electrification of the Broad Street Terminal, Philadelphia, on the assumption that it will be able to handle, in multiple-unit trains during the rush hours, 20 per cent more cars on a given trackage, in and out of the station, than can now be handled in trains drawn by steam locomotives.

[†] Mr. J. A. McCrea, New York Railroad Club, March 17, 1911.

[*] Paper by W. S. Murray, Electrical Engineer, New York, New Haven & Hartford Railroad, presented before the American Institute of Electrical Engineers, June, 1911.

[†] Report of the Public Service Commission of the Second District of the State of New York, 1911.

[‡] Mr. J. A. McCrea, in a paper entitled "Notes on Electrification of the Long Island Railroad." New York Railroad Club, March 17, 1911.

[¶] Mr. W. S. Murray in a paper before the New York Railroad Club, March 17, 1911.

In an address before the New York Railroad Club at its meeting of March 15, 1912, Mr. George Gibbs gave some results of electric operation on the Long Island Railroad for the year 1911. Among these are the following:

Train-mileage	2,388,524
Car-mileage	8,608,300
Number of failures on trains, mechanical and electrical, causing detentions	269
Number of trains detained	302
Total time of train detentions (minutes)	2,824
Average time of train detentions per train (minutes)	9.37
Train-miles per detention	7,900
Car-miles per detention	28,500
Approximate average elapsed time between detentions (hours)	29

Mr. Gibbs also called attention to the fact that these figures, compared with those of a period three years earlier, served to establish the constancy of operating characteristics. Thus, in a total car mileage which has nearly doubled, the total number of failures has greatly decreased and the train mileage between failures has nearly tripled.

In this same address Mr. Gibbs presented the following detailed statement with respect to the New York terminal division of the Pennsylvania Railroad, which operates electrically:

LOCOMOTIVE AND TRAIN MOVEMENTS AND MILEAGE

Number of locomotive movements to and from station	103,982
Average locomotive train movements per day	242
Average multiple-unit train movements per day	188
Average total number of train movements per day	430
Average cars handled per day (locomotive)	1,545
Average cars handled per day (multiple-unit)	562
Total locomotive mileage for the year	909,238
Average mileage per locomotive	25,975
Maximum mileage for one locomotive	56,000

LOCOMOTIVE FAILURES AND DETENTIONS*

	MECHANICAL	ELECTRICAL	MAN	TOTAL
Number of failures	3	11	2	16
Number of trains detained	3	19	4	26
Total time of train detentions due to failures (minutes)	10	134	33	177
Locomotive-miles per detention	303,000	47,850	227,300	35,000
Average time of detention (minutes)	3.3	7.0	8.2	6.8
Average time between detentions (days)	122	33	182	23

MULTIPLE-UNIT FAILURES ON TERMINAL DIVISION

Number of failures in multiple-unit service for the year 1911 on terminal division	3
Number of trains detained by above	3
Total time of multiple-unit train detentions (minutes)	27
Multiple-unit train mileage	296,064
Train-miles per detention	98,600
Train-miles per minute of detention	11,000

"In the above, 'mechanical' failures are those occurring in the running gear of the locomotives, 'electrical,' those in electric apparatus, and 'man,' those due to negligence of the locomotive crews. The total failures for the year, in a locomotive service of over 900,000 miles run, is seen to be 16 only, and the number of trains detained by these failures, 26, resulting in an average time between failures of 23 days, while locomotive-miles run per failure is 35,000. The detentions over the division in multiple-unit service were practically nil, amounting to three only, with a train mileage between detentions of almost 100,000. All of these figures show very satisfactory operating results.

"The record of detentions in the multiple-unit service on the terminal division should not, however, be used as a basis for expected results of such service on the complicated network of lines of the Long Island Railroad. The terminal division multiple-unit runs are for an originating and terminating service on a short stretch of track over which no stop is involved. On the Long Island Railroad, on the other hand, we encounter all the elements of long runs on a surface railroad having a dense traffic and an exacting schedule. Trivial defects even may and frequently do cause delays which affect several following trains. But the figures submitted show very satisfactory performance for service conducted under average steam railroad conditions."[†]

The records of the New York Central & Hudson River Railroad show the delays to the electric service on that road as follows:[‡]

Electric locomotives occasioned . . 337 train-minute delays
Multiple-unit cars occasioned . . 1,106 train-minute delays
Electric locomotives performed about 3,800 miles per one minute detention
Multiple-unit cars performed about 5,700 miles per one minute detention for electrical delays
Multiple-unit cars performed about 9,600 miles per one minute detention for mechanical delays

The average number of miles per minute of delay from all causes attributable to electric operation was 1,200.

The following statement regarding the reliability of electric operation on the New York Central & Hudson River Railroad is pertinent:

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[*] These figures are all based upon locomotive mileage (revenue and light).

[†] Mr. George Gibbs, before New York Railroad Club, March 15, 1912.

[‡] Discussion by Mr. E. B. Katte, meeting of New York Railroad Club, March 15, 1912.

"During the last year (1912), electricity established for itself a new record for reliability on the New York Central. Electric locomotives performed over 4,700 miles per minute detention and the multiple-unit cars over 11,000 miles per electrical detention and over 12,000 miles per mechanical delay. Including all delays chargeable to electric operation, the average miles performed per one minute detention was 4,860 miles as compared with 1,200 miles in 1911 and 1,785 miles in 1910."*

An article presenting a detailed statement of detentions to electric train service on the West Jersey & Seashore Railroad, for the year 1912,† shows "that of the total number of train detentions but 7.478 per cent were caused by motive power failures. Of this percentage, 4.057 per cent of the detentions were caused by failure of train equipment. This statement comprises both mechanical and electrical failures of train equipment.

"Omitting the failures of train equipment from total motive power failures, it appears that 3.421 per cent of the total number of detentions is caused by interruptions to service due to power plant, substations and transmission lines, resulting in 5.925 per cent of the total number of train-minute detentions. This record attests the reliability of the electric system, the total number of failures due to this equipment being exceeded by those due to baggage, express and mail delays, heavy travel, train connections, traffic ahead, held at signal, picking up cars, and signal failures."

302.04 Conclusions with Reference to Comparative Reliability of Steam and of Electric Service: Based upon available information and upon the experience of those who are familiar with the operation of electric traction under steam railroad conditions, it is apparent that reliability of service is greater in electric operation than in steam operation. Increased reliability of service, therefore, is to be accepted as one of the benefits which will accrue to steam roads when electrified. What this benefit is worth to the railroad securing it must for the present remain indeterminate.

302.05 Possible Return through Intensive Use of Railroad Property: The fact that smoke from steam locomotives will disappear when the service is electrified, suggests the possibility of utilizing space over tracks for buildings and other purposes. It has been urged that in Chicago much of the expense of electrification could be returned to the railroad companies through the more intensive use of the properties they now hold; that the rights-of-way which are now occupied only by railroad tracks might also constitute the site of extensive buildings to be erected over the railroad tracks. The fact that a great railroad company in another city has found it possible to erect certain structures over its right-of-way has done much to stimulate interest in this phase of the electrification problem as it affects the situation in Chicago.

The possibilities of such a development must, of course, be at once admitted. From a technical point of view all of the tracks within the city of Chicago might be covered and many activities incident to the commercial and industrial life of the city could be provided for in structures erected above them. But the proposal presents limitations which should be noted:

1. The fact should be recognized that the only asset which is assumed to underlie such a procedure is the land value involved.
2. The possibility of erecting buildings over the right-of-way of a railroad company suggests a source of income to be had without cost, but the return must carry an investment as great as that involved in other similar buildings, with the land value omitted.

The land, moreover, is not free for purposes of intensive use, because its occupancy by the railroad requires the development of a substructure between foundation supports, and the limits of clearance required for railroad operation must be regarded in the erection of the building. Obviously, the return to the railroad from such a source is limited by the cost of preparing the right-of-way for the reception of the proposed buildings; by the value to the railroad company of having its operation open to the air and sunlight; by the value to the railroad company of having intertrack spaces unobstructed by building columns; and by the cost of other real estate in the immediate vicinity which might serve all the purposes which could be met through the intensive use of the railroad property. Only in cases where other land adjacent to the railroad possesses a very high value could the company afford to sacrifice

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*Mr. E. B. Katte, meeting of New York Railroad Club, March 31, 1913.

†Mr. B. F. Wood, General Electric Review for November, 1913.

the advantage of open-air operation and be at the expense of preparing foundations and substructure on which to erect buildings over its track, assuming the motive behind such a procedure to be the expectation of gain of revenues to be derived from buildings thus constructed.

Nearly half of the track mileage comprehended by the Committee's plan of electrification lies in switching yards, and most of these are on the outskirts of the city. Land values in these localities have not yet reached a point which will permit of the profitable intensive use of structures which might be erected over the areas covered by such switching yards. There are locations here and there where the terminal operations of the railroads are congested and where activities might be extended from a single level to two or more levels. There are locations, also, where in the development of future terminal stations various activities may have their place in connection with, and even above, the tracks of railroads; but a general proposition to improve intensively, as a means in the development of revenue, the properties already occupied by that portion of the 3,000 miles of railroad track which is remote from centers of congestion must, under present conditions, be considered impracticable.

The practicability of applying an intensive process to the improvement of railroad property would appear to increase as attention is concentrated upon properties near the heart of the city where adjacent land areas are most valuable. Difficulties, however, appear in the development of the proposed procedure in such localities. For example, the right-of-way of the Illinois Central between 12th Street and Randolph Street is held under a tenure which absolutely prohibits the railroad company from building any structure at a greater height than 15 feet above its right-of-way. Even an ornamental parapet wall which was once erected on the margin of Grant Park was not approved and has been removed. Much of the property occupied by railroads in the downtown district has been acquired through right of eminent domain, and property thus acquired could probably not be utilized for the erection of buildings over railroad tracks except as such buildings might be necessary for the purposes of the railroad company.

Extending the discussion of this phase of the question, it may be said that the land titles of railroads are usually acquired through one of the following methods:

1. By deed in fee simple.
2. By deed on condition, or limiting the use of premises conveyed to railroad purposes or railroad right-of-way.
3. By grants of right-of-way by individuals.
4. By grants by the United States or by the state governments.
5. By condemnation.
6. By licenses, parole gift or prescription.

In all of these methods except the first, the abutting owner of the land retains a substantial interest in the right-of-way. As these different methods are used with different parcels of land adjoining each other, and as many of the rights acquired by railroads are mere easements for right-of-way, leaving the fee title outstanding in individuals, usually abutting owners, the problem must be solved by assuming that only such use as the law permits of easements acquired for railroad purposes will be allowed.* A brief summary of the law on this question is as follows:

> "The law will permit the railroad company the widest use of its right-of-way consistent with the object of the grant and the operation of the railroad, but where an additional servitude not in any wise connected with the operation of the railroad is imposed upon the right-of-way the fee owner is entitled to a remedy, ordinarily for damages; sometimes injunction will be granted until by condemnation the value of the additional use is determined.
>
> "Under this state of law, all cases are dependent upon the particular facts of the particular case; thus, it is universally held that telephone lines erected upon a railroad right-of-way constitute an additional burden for which additional compensation to the abutting owner is required. Telegraph lines, even though only partly used for the operation of the railroad, do not constitute an additional servitude.
>
> "Elevators, lumber yards and boarding houses do not constitute an additional servitude, and in one case a storage warehouse where 75 per cent of the product was shipped over the railroad was held not to create an additional servitude.
>
> "A review of the cases in the two citations above mentioned will make the distinction clear. A railroad company might erect an office building over its right-of-way for its general offices without compensating the abutting owners. On the other hand, the erection of an office building for general commercial purposes not connected with

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* Substantially all of the law on this question is digested in Volume 7, L. R. A., page 200, and Volume 36, L. R. A., new series, page 512.

> the railroad business would be held to be an additional servitude.
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> "A hotel largely for the benefit of railroad employes would not be an additional servitude, whereas a hotel for the general entertainment of the public would be."*

It should be clear that the erection of buildings over a railroad right-of-way in the city of Chicago, for the purpose of mere profit unconnected with the main business of the railroad company, would impose an additional servitude, and as the company would have no right to condemn property for such purpose the remedy of the abutting property owners would be either injunction or damages, depending upon the particular facts in each case.

All things considered, it would seem inexpedient to attempt to determine any money value to represent the possible return which might accrue to the railroads of Chicago as a result of electrification, through the possibilities of erecting income earning structures over their rights-of-way.

302.06 Possibilities of Return through an Extension of Miscellaneous Electric Services: The railroads are at the present time consumers of electricity. They have offices, stations, shop buildings and railroad yards to illuminate, and they also have electrically driven machinery performing a variety of services for which current must be supplied. Under present conditions each railroad provides for its necessities in such manner as seems to it wise. Some companies have central electric generating stations of considerable capacity; others have a number of scattered generating plants; and still others purchase the current they require. It is usually assumed that one of the sources of return to a railroad company, made possible through electrification, is that of effecting economy through the use of current from its central power station for all these incidental purposes. It has, for example, been suggested that railroads at present purchasing current for lighting could, with a great central power station erected for traction purposes, effect some economy in taking current for general purposes from such a source of supply, and that the saving thus effected should be made to appear as a credit against the cost of electrification; also, that companies having several small and inefficient plants for generating the current they now need would effect economy in taking this current from the larger power plant which electric traction would make necessary. It has been suggested, furthermore, that even those railroads having central power stations of considerable capacity and of reasonably high efficiency, for use in supplying the incidental needs referred to, could effect some economy by transferring the activities of such a plant to the larger and more efficient plant which electric traction would make necessary.

In dealing with this question, inquiries were made of the several railroads affected concerning existing methods employed in securing electric energy, in the expectation that an estimate could be developed of the possible saving which would result from the transfer of all such demands to the great central generating station required for electric traction. It early became apparent, however, that most roads were already in need of more power than they were using and that, in the event of electrification, the whole scheme of track and yard lighting would be very much extended. All roads have more or less machinery in shops, in roundhouses and in office buildings, which is steam driven and also some which is electrically driven. There is a disposition to extend the existing electric power load, and it is impossible to estimate the extent to which it would be increased in the event of complete electrification. Moreover, an extension of the electrically driven load as supplied by shops and office buildings involves capital costs, which are not included and which, in the nature of the case, cannot be included, in the Committee's estimates covering the cost of electrification. It would be inadmissible to include an estimate of profits where the installation cost of plant is excluded.

It should be apparent, moreover, that the assumption that electric lighting and power loads must be considered a necessary part of any general scheme of electric traction is not in itself well founded. The problem of electrification should properly stand upon its own feet, carrying its own costs and receiving credit for the return which it can be depended upon to give. Any theory of return which required the inclusion of profits made possible through the inclusion of

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*Statement prepared by Mr. Harrison B. Riley.

return on company lighting, might also justify the inclusion by the railroad company of commercial lighting and power loads remote from its own activities.

From such study of this aspect of the problem as has been possible, the conclusion has been reached that it will be impracticable to determine quantitatively the extent of the advantage, if any, which the railroads would secure in the event of electrification through the more efficient handling of electric loads now imposed by their various incidental activities.

302.07 Health, Comfort and Convenience, as Affected by Electrification: The effect, if any, to be produced upon the health of the community through the elimination of steam locomotives and the introduction of electric locomotives, must have its advent chiefly through changes produced in the atmosphere. If electrification were to result in a material reduction of atmospheric pollution and if it could be shown that the removal of such pollution would favorably affect the health of the community, electrification could be urged as a health measure. An examination of the problem, however, has shown (chapter 114) that the substitution of electric operation for steam operation upon the railroad terminals of Chicago would reduce the smoke in the atmosphere by a comparatively small amount, and a review of the literature on the subject has shown also (chapter 101) that the amount of smoke found in the atmosphere even of a smoky city is not disastrous to health, though sanitary experts agree that it has detrimental effects. On the other hand, so far as is known, electrification would introduce no condition prejudicial to health.

People are comfortable when they are at ease, mentally and physically; when they are contented and undisturbed; when they are satisfied that conditions about them are substantially what they ought to be. They are convenienced when their movements are made certain; when their time is saved; or when their personal plans are promoted. Will electrification of the railroads of Chicago make more agreeable the daily life of its people? Will it make existence more comfortable and enjoyable? The answer to these questions must undoubtedly be in the affirmative, though the extent to which the people will profit and the precise way in which the gain will appear will depend upon many things.

The suppression of local smoke and fuel dust, even to the limited extent which may be secured through electrification, cannot fail to affect favorably the comfort and convenience of people. The gains in this respect would be enjoyed both by those who live or work in the vicinity of the railroads and by those who travel. As shown elsewhere the effect would be chiefly local to the railroad routes but within a limited area it would be substantial.

Finally, comfort and convenience would be enhanced by electrification through a reduction in the amount of noise. All of those sources of disturbing sounds which are caused by the steam of the locomotive would disappear. The heavy discharge of the exhaust when the locomotive is starting and accelerating its train, and the sharper blow of the safety valves, would cease to disturb and offend. These sounds constitute a large part of the objectionable noise which arises from the operation on through tracks and in railroad yards.

The preceding considerations show that electrification will contribute to increased convenience and comfort in the following respects:

1. By permitting a greater celerity of train movements.
2. By increasing the reliability of train movements.
3. By reducing localized smoke sources.
4. By reducing noise.

302.08 Loss and Damage to Property: A previous discussion (section 101.48) has served to emphasize the fact that there exist no definite or reliable standards of measure for determining the money value of losses which result from the presence of smoke in the atmosphere. It cannot be assumed, for instance, that a large city ought to be as clean as a country village, nor can any ratio of cleanliness be established. It is obvious that the diversified activities of the larger communities are productive of a greater degree of street dust and other forms of atmospheric pollution, as well as of smoke, than those of the small towns. The large cities are, in most cases, more congested than the small ones, and this congestion is in itself productive of a greater degree of atmospheric pollution, whether of a preventable or unpreventable nature.

It has been shown also that the deleterious effects of smoke and those of other kinds of atmospheric pollution are so similar and so closely related as to render it difficult to segregate the two or to differentiate between them.

The smoke of Chicago arises from many different sources, from domestic fires, from the fires of steam boilers and from metallurgical and other industrial fires as well as from those of steam locomotives. Smoke from locomotives constitutes only a small portion of the total smoke in the atmosphere (chapter 106), and, consequently, of all the loss and damage occasioned by smoke, a small portion only will be eliminated through the electrification of railroads. As the whole loss and damage occasioned by smoke is indeterminate, that portion of the whole which would be eliminated through electrification must also be indeterminate.

302.09 A Summary of Indeterminate Results: The work of changing the railroad terminals of Chicago from steam to electric operation will affect a vast establishment. The operating procedures incident to the activities of this establishment are varied and complicated. It cannot be assumed that any analysis which anticipates experience under the new conditions introduced by electrification will be perfect or complete. The discussions of the preceding sections are, therefore, to be regarded as a presentation of those indeterminate benefits which are most obvious and probably most important. They may be summarized as follows:

1. The electrification of Chicago's railroad terminals will result in some increase in the capacity of existing trackage and terminals. In locations where operation under present conditions is congested, electrification will give relief and by so doing will constitute an improvement to the existing establishment. In locations where there is at present no congestion of traffic, electrification will constitute, in effect, an enlargement of existing facilities and by so doing it will postpone the day when additional facilities will be required.

2. Electrification will contribute to increased celerity and reliability in the movement of railroad equipment on the electrified trackage.

3. Electrification may open the way to the intensive use of railroad property. It will contribute to the development of conditions which will permit double-decked freight and passenger terminal stations, and it may open the way for the utilization of space above tracks for buildings to be erected for general business purposes. The value, however, of the return which may be possible through the intensive use of railroad property in Chicago is speculative and, considered as a present-day asset, it cannot be large.

4. Electrification will permit an extension of electric service beyond that which is necessary for the use of trains. As a possible source of benefit it is one which would be immediately available upon the completion of electrification. It is incidental in character and not large in amount.

5. Electrification will contribute to the comfort and convenience of people and by so doing will result indirectly in benefit to the railroads.

6. Electrification will reduce the loss and damage to property now occasioned by the presence of smoke in the atmosphere, but the value of this is indeterminate.

303. THE EFFECT OF ELECTRIFICATION UPON SAFETY

SYNOPSIS: This chapter presents the results of a study concerning the relative safety of steam and of electric railroad operation. It shows that the changes incident to electrification will introduce conditions some of which involve added hazard and some, increased security. The conclusion is reached that the net effect on safety, favorable or otherwise, which will result from the electrification of the steam railroad terminals of Chicago, will be slight.

303.01 Safety: Safety is a relative term. As applied to electric operation it may be defined, for the purposes of this study, as the comparative liability of accident and personal injury from railroad operation with electric power and with steam locomotives. Its consideration constitutes a factor of importance in the work of the Committee, since the extent to which safety is affected by the electrification of a steam railroad is an argument which may be advanced in favor of, or against, the change; it constitutes one of the returns to be expected from electrification. Whether, as such, it is positive or negative in its effect must be determined from the facts. If it should be made apparent that the introduction of electric operation will materially reduce the usual hazard to the public, to railroad employes, to passengers, or to all of these, electrification might be regarded as justifiable as a means of procuring greater safety in operation.

303.02 Available Data:[*] Electric operation under steam railroad conditions is a development of recent years and the number of examples of such installations is still limited. For this reason, the volume of data which can be used in a comparative study of the relative safety of steam and of electric service is meager. Moreover, direct comparisons are rendered difficult by the fact that electrification has generally brought with it other physical changes affecting operation so that, in addition to the change from steam to electric operation, other new conditions have been introduced. The result is that traffic conditions under electric or under joint steam and electric operation are materially different from those under steam operation. Such facts with reference to electric railroad operation as are available, whether of domestic or of foreign origin, relate for the most part to passenger service. They are, therefore, not to be accepted as entirely applicable to electric operation of freight service or to electric operation of both freight and passenger service. These are matters to which due consideration must be given in the process of forming an estimate of the relative safety of electric operation as compared with that of the present steam operation on the Chicago terminals, where only a small part of the electric installation will be required for passenger service and a much larger part will be required for the more complex operations of freight, yard and transfer services.

303.03 Steam Railroad Accidents:[†] Statistics prepared by the Interstate Commerce Commission show the number of persons killed or injured by the operation of interstate steam railroads during the 26-year period, 1888 to 1913, inclusive. The results are segregated to show the number of trespassers and "other persons" killed or injured for the period from 1890 to 1913, inclusive. A summarized statement, covering the classes of persons affected, is set forth by table CDXXIV.

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[*] The following sources of information have been consulted and facts derived from them have been analyzed:

1. Official quarterly "accident" bulletins of the Interstate Commerce Commission. These bulletins give a list of all accidents resulting in injury to persons, equipment or road-bed, arising from the operation of railroads used in interstate commerce. They are compiled from reports made under oath by officers of railroad companies to the Commission, as required under the "accident law" of May 6, 1910.
2. Reports of public service commissions of certain states. These reports often present statistics similar to but less comprehensive than those contained in the reports of the Interstate Commerce Commission.
3. Reports of the Bureau of Railway News and Statistics. These are issued annually and contain chapters on accidents together with a summary of accidents on American and on foreign railroads. They are compiled from various sources and are general in character. They do not often present in detail an analysis of the question of hazard.
4. Reports of foreign bureaus such as the English Board of Trade. These are quite similar to the Interstate Commerce Commission reports. Information with reference to special accidents and conclusions with reference to causes are generally more complete than the corresponding information given in the American reports.
5. Replies to inquiries addressed to certain railroad companies owning electrified lines. These, it should be noted, are in most cases lacking in detail and are inconclusive.

Information relating to electric operation, as obtained from the sources mentioned, is relatively meager.

[†] Archives of the Committee, Vol. L 8.

TABLE CDXXIV. NUMBER OF PERSONS KILLED OR INJURED IN RAILROAD ACCIDENTS IN THE UNITED STATES DURING THE PERIOD 1890 TO 1913, INCLUSIVE

Class of Persons Affected	Number Killed	Per Cent of Total	Number Injured	Per Cent of Total
1	2	3	4	5
Passengers......	7,934	3.9	1,328,888	87.7
Employes......	66,495	32.7		
Other persons:				
Trespassers....	108,124	53.6	118,057	7.8
Non-trespassers	19,615	9.8	68,832	4.5
Totals.........	202,168	100.0	1,515,777	100.0

A study of the statistical record of accidents shows that of 202,168 persons killed, 127,739, or 63 per cent, are classed as "other persons," that is, they are neither passengers nor employes of railroad companies.

Of the passengers and employes affected, a comparatively small number are killed, whereas of the "other persons," including trespassers, affected, the number killed approaches the number injured.

While considerable attention has been directed by the public and by railroad officials to the question of eliminating grade crossings, it is interesting to note the number of accidents occurring at such points as compared with the number occurring at other points along the track. The records of the Interstate Commerce Commission covering the five-year period from 1905 to 1909, inclusive, show that 4,261 persons were killed at highway crossings and 17,861 persons were killed at "other points along track." A total of 8,830 persons were injured at highway crossings and 10,686 persons were injured at "other points along track."

The German statistics, like those of the Interstate Commerce Commission of the United States, present total figures only. An attempt has been made to obtain additional information that will provide a basis upon which may be determined the number of accidents per mile of track or per train-mile and the ratio of the number of accidents to the number of passengers carried. This effort has resulted only in illustrating the fact that, in the case of the German railroads, approximately one-half of the persons killed or injured were employes and passengers, the remainder being made up of trespassers and "other persons." In view of the fact that on the continent of Europe walking on railroad tracks is forbidden by law, the number of accidents resulting in injury or death to trespassers should be less than in this country, since here the railroad right-of-way is often used as a highway. However, statistics compiled from the reports of the "Kaiserlich Deutsches Reichs-Eisenbahn-Amt" indicate that there is considerable trespassing. These statistics, for the years 1909 to 1911, inclusive, are presented as table CDXXV.

Certain classes of railroad accidents may be regarded as unavoidable. Among these may be included accidents due to such causes as landslides and washouts, those due to gross negligence, illness or failure of employes, and those due to other causes which may rightly be regarded as beyond the control of the railroad companies.

In a second class of accidents may be included

TABLE CDXXV. NUMBER OF PERSONS KILLED OR INJURED IN RAILROAD ACCIDENTS IN GERMANY, 1909, 1910 AND 1911

Classes	1909		1910		1911	
	Killed	Injured	Killed	Injured	Killed	Injured
1	2	3	4	5	6	7
Passengers:						
In accidents to trains	25	305	2	422	14	324
Other accidents:						
Without fault of their own	3	68	4	72	3	52
As result of their own carelessness	93	194	91	178	98	207
Totals	121	567	97	672	115	583
Employes on duty:						
In train accidents	13	180	14	202	36	179
In other accidents:						
Through their own carelessness in trains	79	286	62	297	64	280
In making up trains	51	259	60	230	55	263
In coupling cars	87	184	92	175	98	173
While on tracks in way of moving cars or trains	242	237	240	218	243	235
Through other forms of carelessness	61	193	75	219	67	213
Totals	533	1,348	543	1,350	563	1,343
Post, telegraph, police and customs staff	14	50	6	68	13	70
Trespassers, including employes not on duty	324	257	280	248	324	271
Suicides	402	33	338	27	369	326
Totals	740	340	624	343	706	667
Totals, all classes	1,394	2,255	1,264	2,365	1,384	2,593

those which may to some extent be avoided by the adoption of improved equipment and appliances, by better construction and by the more rigid enforcement of suitable rules and regulations. The equipment of locomotives with driver brakes, the equipment of cars with automatic couplers to permit coupling and uncoupling without requiring men to go between cars, and the enforcement of uniform rules applicable to freight cars with reference to the location of such appliances as grab-irons and running boards, have all had their effect in reducing the number of accidents.* Although designed chiefly for the protection of trainmen and railroad employes, such provisions have doubtless aided in the prevention of accidents to others. Railroads have in recent years stimulated the "safety first" movement by processes of education and by the enforcement of rigid rules, regulations and systems of checking, with results the value of which cannot be accurately estimated.

The statistical record shows that all these influences have had their effect upon safety in steam railroad operation. The number of accidents incident to the handling of equipment, when compared with the number of cars handled or movements made, has steadily diminished in recent years.

303.04 Electric Railroad Accidents: Existing steam railroad electrifications are discussed elsewhere in this report (chapter 205). The more important American steam railroad electrifications, named in order of their installation, are as follows:

1. *Long Island Railroad:* This road operates an extensive suburban and city line. Passenger service only is operated electrically and multiple-unit trains are employed in this service. Through passenger trains and freight trains are operated by steam locomotives over some of the electrified lines. The third rail system is used. This road is now conducting traffic under conditions materially different from those which existed under steam traction, the traffic having grown enormously and the line of an important portion of the system having been changed from a steam railroad on the surface of city streets to an electric railroad, part of which is elevated and part of which is underground. The train make-up and frequency are entirely different from those of steam operation (section 205.03).

2. *West Jersey & Seashore Railroad:* This road operates passenger service electrically with multiple-unit cars on a cross country line between Camden and Atlantic City, N. J. Freight is handled by steam locomotives over the electrified tracks. The third rail system is used on the line, with the exception of a short stretch of overhead construction at one of the terminals. Upon the installation of the electric system much of the line was rebuilt as a double-track road. The business of the railroad has increased under electric operation (section 205.08).

3. *New York Central & Hudson River Railroad:* This road operates electrically its New York City terminal and its approaches, including the Park Avenue tunnel and viaduct. It also operates electrically busy suburban sections of two main line divisions. Passenger service only is operated electrically, electric locomotives and multiple-unit cars being used. Freight traffic is handled by steam over some of the electrified lines. The third rail contact system is employed. Service has been conducted into the new terminal under extraordinary difficulties during construction, which is still (1912) in progress (section 205.04).

4. *New York, New Haven & Hartford Railroad:* This road operates a busy suburban section of its main line into the New York City passenger terminal of the New York Central Lines. Both electric locomotives and multiple-unit cars are used in passenger service. Freight service is operated by electric locomotives. Some yard service is operated electrically. The overhead contact system is used, but locomotives and motor cars are equipped for operation into the New York passenger terminal over the third rail system of the New York Central & Hudson River Railroad (section 205.05).

5. *Pennsylvania Railroad—New York Terminal:* This road operates passenger service almost entirely by electric locomotives, only a few multiple-unit cars being used. The road lies largely in tunnels and on embankments. The third rail system is used. It is an entirely new railroad and has been operated electrically from the start (section 205.06).

6. *Spokane & Inland Empire Railroad:* This road operates electrically a system of interurban and city traction lines. It also operates a long single track division on which the business is essentially long distance freight and passenger. Freight trains are hauled by electric locomotives. Passenger service is conducted by motor and trailer cars. The single-phase system of traction with overhead contact is used on the freight division. This division is entirely new and has been operated electrically from the start (section 205.09).

7. *Butte, Anaconda & Pacific Railway:* This is an electrified single track line extending from Butte to Anaconda, Mont. The business consists chiefly of the handling of copper ore from Butte to the smelters. Both freight and passenger trains are hauled by electric locomotives.

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* Federal Safety Appliance Act of 1893, amended in 1903 and 1910.

The 2,400-volt direct current system with overhead contact is used (section 205.10).

The American short tunnel line electrifications are as follows:

1. *Baltimore & Ohio Railroad:* This road operates electrically a tunnel line under the city of Baltimore. This tunnel is used for both freight and passenger trains, which are hauled through it by means of electric locomotives, the steam locomotives not being disconnected. The third rail system of traction is employed (section 205.16).

2. *St. Clair Tunnel of the Grand Trunk Railway:* Freight and passenger trains are operated through this tunnel by electric locomotives. Overhead contact is used (section 205.17).

3. *Detroit River Tunnel of the Michigan Central Railroad:* Freight and passenger trains are operated through this tunnel by means of electric locomotives. The third rail system is employed (section 205.19).

4. *Cascade Tunnel of the Great Northern Railway:* Freight and passenger trains are operated through this tunnel by means of electric locomotives. A two wire overhead contact is used (section 205.18).

5. *Hoosac Tunnel of the Boston & Maine Railroad:* Freight and passenger trains are operated through this tunnel by means of electric locomotives. The overhead contact system is employed (section 205.20).

It will be seen that, in all cases, electrification of steam railroads in this country has been adopted as a means of performing some special service or meeting some special conditions. Many of the electrifications may be considered pioneer installations for the particular conditions involved and, therefore, operating methods and details of apparatus in many cases have not been perfected to a point which insures normal constancy of results.

Examples of steam railroad electrifications in England and on the continent of Europe are described elsewhere in this report (chapter 205.20). The principal foreign electrifications of steam railroads or of roads operating under steam railroad conditions are as follows:

1. *North Eastern Railway, England:* This road operates electrically a busy suburban passenger service in a manufacturing and colliery district. Motor car trains are used. Freight service is still handled by steam locomotives. The third rail system is employed. This is one of the largest steam railroad electrifications in England (section 205.24).

2. *Lancashire & Yorkshire Railway, England:* This is an important electrified steam railroad serving the suburbs of Liverpool. Passenger service is operated electrically by means of motor car trains. Freight service is conducted by steam locomotives. The third rail system is employed. The road has a connection with the Liverpool Overhead Railway (section 205.25).

3. *London, Brighton & South Coast Railway, England:* This road operates electrically terminal and suburban lines for passenger service only. Motor car trains employing the high tension overhead contact system are used. Steam operation continues over some of the electrified lines (section 205.28).

4. *Orleans Railway, France:* This road operates electrically a terminal and suburban service through a long subway approach to the terminal station. Passenger service is conducted with motor cars and electric locomotives. Freight service is operated to a limited extent with electric locomotives. Steam operation of both passenger and freight service is also conducted over a part of the electrified division. The third rail contact system is used (section 205.34).

5. *Prussian State Railways, Germany:* Several of the sections have for several years been operating electrically, to a limited extent, both passenger and freight service. Different systems of traction are used, but in all cases overhead contact is employed. In the majority of cases electric locomotives are used. All of these sections may be considered trial installations, the purpose being to provide a practical means of solving certain operating and technical problems (section 205.39).

6. *Loetschberg-Simplon Tunnel Railway, Switzerland:* This is a heavy grade passenger and freight railroad through and over the Bernese Alps. It forms a new link in a through line from Germany to Italy. The line has many tunnels two of which are more than eight miles in length. Service is conducted by electric locomotives. The Simplon tunnel portion of the line has been in operation since 1906. The Loetschberg tunnel has only recently been electrified and placed in regular operation (sections 205.46 and 205.47).

7. *Italian State Railways, Italy:* Included in these are the Milan-Porto Ceresio Railway, an important interurban railroad employing the third rail direct current system; the Valtellina Railroad, which conducts a heavy passenger and freight traffic by means of motor car trains and electric locomotives; lines around Genoa and the Gulf, including two parallel heavy grade freight and passenger lines out of Genoa, the Giovi Railway, the Succursale di Giovi Railway, a heavy grade freight and passenger line from Savona to Ceva, and the Genoa-Savona Railway, which forms a connecting link between these roads; the Mt. Cenis Railway from Bussoleno to Modane, a heavy grade mountain railroad operating freight and passenger service, almost half of which is in tunnel sections; and the Turin-Pinerola Railway, serving the suburbs of Turin. All of these roads, with the exception of the

Milan-Porto Ceresio Railway, use the three-phase overhead contact system with electric locomotives (section 205.58).

The Committee has endeavored to obtain as complete information as possible concerning accidents on all lines which have been converted from steam to electric operation, both in America and in other countries. Letters of inquiry were sent to officials of the various roads asking for a statement of all facts of record. In a number of cases replies were obtained only after repeated requests, and in some instances no replies have been received. The information obtained from these sources is fragmentary and, on the whole, unsatisfactory.* Difficulties in supplying such information arise in part from the unsettled state of electric railroad practice. Among the factors influencing the returns, the following are significant:

1. In many cases electric construction on portions of the total trackage affected has continued while electric operation has been progressing on other portions; all accidents, whether from construction or operation, have not infrequently been charged to electric operation.
2. Many accidents during the construction period charged to electric operation make the accident record abnormally large.
3. In most cases steam and electric operation are so closely related that it is difficult to classify accidents, especially in yards and shops.

Uncertainties thus arising make it undesirable to set forth accident statistics for steam railroad electrifications by roads. A summary of the facts for the three years 1911, 1912 and 1913, as they have been ascertained for three important American steam railroad electrifications has, however, been compiled and is given as table CDXXVI.

A detailed study of the facts presented by table CDXXVI, shows that, for a considerable period after initial electrification, the number of accidents has been relatively large. This is due to the fact that employes have been unaccustomed to the electrified conductors and rolling stock in the vicinity of which they have been required to work and have failed to appreciate the danger thus arising. An analysis of the statistics presented indicates the following general classification of accidents and their main causes:

1. Accidents to Passengers: These were all of a minor character, such, for example, as injury caused by falling electric light bulbs, injury to clothing due to defective insulation or heaters, and injuries occasioned at stations where passengers have been struck by fragments of broken contact shoes.
2. Accidents to Employes: These are found to have been due chiefly to contact with electrified power conductors while repairing track and trolley supports, inspecting rolling stock on electrified track, and through contact with overhead wires while on tops of cars.
3. Accidents to "Other Persons": These accidents have varied widely. In some cases they have been due to contact with the electrified conductor while trespassing; in other cases trespassers have climbed, for unknown reasons, catenary bridges or high tension transmission poles.

TABLE CDXXVI. ACCIDENT STATISTICS ON CERTAIN ELECTRIFIED STEAM RAILROADS IN THE UNITED STATES. 1911, 1912 AND 1913

Classes	1911		1912		1913	
	Killed	Injured	Killed	Injured	Killed	Injured
1	2	3	4	5	6	7
Employes	5	54	4	57	9	114
Other persons	2	6	7	7	11	18
Passengers	0	1	0	1	0	13
Totals, all classes	7	61	11	65	20	145
Accidents per Hundred Track-Miles						
Employes	1.382	14.920	0.608	8.680	0.910	11.486
Other persons	0.553	1.657	1.065	1.068	1.110	1.814
Passengers	0	0.273	0	0.152	0	1.320
Totals, all classes	1.935	16.850	1.673	9.900	2.020	14.620
Accidents per Ten Million Car-Miles						
Employes	2.77	29.86	1.32	18.81	2.32	29.35
Other persons	1.11	3.32	2.31	2.31	2.83	4.64
Passengers	0	0.55	0	0.33	0	3.35
Totals, all classes	3.88	33.73	3.63	21.45	5.15	37.34
Thousands of Car-Miles per						
Employe	3,620	3,348	7,571	5,313	4,316	3,407
Other person	9,050	3,013	4,326	4,326	3,531	2,158
Passenger	0	18,081	0	30,285	0	2,988
Totals, all classes	2,581	2,964	2,753	4,659	1,942	2,678

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* Archives of the Committee, Vol. L 8. Article on "Safety."

Of the fatalities to employes under electric operation, 60 per cent are the result of falling from cars or getting on or off cars, and 50 per cent of the accidents to passengers occur in this manner. Obviously, this class of accidents is unaffected by the system of traction. By far the largest number of accidents occur to "other persons." Of the total number, 80 per cent of this class are trespassers. Of the accidents to trespassers, 50 per cent result fatally. Such accidents are probably beyond the control of the railroad, for, while everybody knows the danger attending trespass upon railroad property, the facts seem to be that no branch of the government, national, state or municipal, has thus far seriously attempted to prevent such trespassing. A city ordinance prohibits trespassing on the elevated tracks of steam railroads within the city of Chicago, yet many accidents resulting from such trespassing occur.

Five of the electric railroads in England made reports relating to accidents. Three of these reports gave statistical facts.

The North Eastern Railway reported that during the year 1911 there occurred 117 injuries to passengers, employes and others. Of this number only six were said to be due to electrical causes. Since the information is not explicit, the actual number of injuries due to electrical causes may have been somewhat in excess of that stated in the report. It appears, however, from a comparison of these data with the results of steam operation on the line previous to its electrification, that the casualties from electrical causes have not been great in number. The engineer who formulated the report stated that it is "common knowledge on the line that fewer accidents occur on electric than on steam railways."

The Metropolitan District Railway of London reported that out of a total of 196 injuries from all causes, only four were due to the presence of electric devices. Most of the injuries occurred to passengers as the result of falling while on stairways or when entering or leaving trains. Since the number of miscellaneous accidents to employes, who are generally in danger of coming in contact with electric appliances, has decreased under electric operation (although it is not certain that this decrease represents normal results over a term of years), it is evident that electric operation on this road has developed no extra hazard as regards contact with electric apparatus.

The Metropolitan Railway, also an underground line in the city of London, introduced electric traction on its lines within the city at the same time as did the Metropolitan District Railway. This railroad, however, keeps no record of accidents, and submitted only a statement concerning the actual compensation paid on account of accidents by the railroad as a whole before and after electrification. These figures indicate that there was a very marked decrease in the compensation for accidents to passengers and a small increase in the compensation for accidents to employes, the figures in both cases being on a train-mile basis. It is difficult to draw any direct conclusion from the figures submitted, but they do not appear to indicate that any additional hazard has developed from electric operation.

The London, Brighton & South Coast Railway, which is a surface line using high tension overhead trolley, gave no statistical facts. It was stated that no separate record had been kept of accidents in steam and in electric services, which are conducted over the same tracks. The consulting engineer of the railroad stated in a paper before an engineering society, that during the first year of electric operation only two accidents occurred from electrical causes and that both of these were due to gross negligence on the part of employes.

Of the electric railroads in France only two reported. One, the Paris-Orleans Railway, presented tabular information showing that, of a total of 52 persons injured on the electric line, four were injured in accidents due to electrical causes. These four accidents occurred to employes as a result of contact with apparatus on the cars or track or in the power stations. Compared with the reports of English railroads, the number of electrical accidents on the Paris-Orleans road appears to be relatively high.

From Holland the Rotterdam-Hague electric line, which has an extensive passenger service operated by motor cars, reports that there have been no injuries to passengers or employes since the opening of the line in 1908. This showing is extraordinary and has not been duplicated, so far as is shown, on any other road. It seems certain, however, that no extra hazard has been introduced on this road as a result of electric operation.

No official information has been obtained by the Committee from electric railroads in Germany and in Italy.

303.05 Comparisons Based upon an Analysis of Conditions: The incomplete character of existing records suggests the practicability of reaching a more definite conclusion from an analysis of the conditions existing under steam and under electric operation. Such an analysis has been made, involving the following considerations:

1. An analysis of the causes of railroad accidents generally and a separation of those which would be affected by a change of motive power.
2. The application of an estimate based on experience as to the relative hazard in the use of apparatus and devices involved in steam and in electric railroad operation.

The record of this analysis is too voluminous for presentation in this report. It makes apparent the fact that where the third rail system is employed there is not only danger of shock from accidental contact with the charged rail but there is danger from the third rail as an obstruction in the path of those seeking to cross tracks. Where the overhead contact system is used there exists some danger from contact with overhead wires by trainmen on tops of cars. Employes on the track are probably more exposed to danger from the quiet movement of electric trains than from the noisier movement of steam trains, though the hazard thus arising is largely offset by the greater opportunity for vigilance on the part of the motorman. Employes working on or around electric locomotives or cars and in electric power stations and substations are subjected to some hazard through the possibility of accidental contact with electric apparatus. It would appear from all deductions made from the analysis, that the change from steam to electric operation will bring with it no added risk to the safety of passengers; that the risk to employes will be increased by an amount chargeable to the added hazard of the electrified conductor; and that the risk to trespassers will be increased.

The analysis shows also that electrification introduces conditions which distinctly promote increased safety. For example, electric traction substitutes boilers in power plants for boilers in locomotives. The power plant boilers are comparatively few while those of locomotives are numerous, and there seems to be less hazard to employes from the possibility of burning or scalding under electric operation than under steam operation. The absence of steam and smoke in electric traction eliminates hazard to employes which may result from the obscured vision caused by escaping steam and smoke. Electrification makes possible changes in operating conditions, the effects of which tend to increase safety. There is an entire absence of locomotive movements to and from coal and water stations and there are fewer movements in the handling of suburban passenger equipment in and out of terminals. Every movement of locomotives or cars involves a certain hazard, and the elimination of movements in the accomplishment of a given purpose reduces the total hazard.

The extent to which the added hazard attending electrification will, in the future, be further reduced or neutralized by improvements in the design of equipment, by a simplification of operating procedures, by the enforcement of proper rules and regulations for the protection of men and by the introduction and maintenance of mechanical safeguards, cannot be definitely shown. The experience of electrified roads seems to indicate that with the increased risk have come safeguards and changes, the effects of which have largely or entirely neutralized the new sources of danger.

303.06 Conclusions Concerning the Effect of Electrification on Safety: The information presented by the preceding sections and, in more detailed form, by the Archives of the Committee, is insufficient to supply a basis from which to draw definite conclusions regarding the relative safety of steam and of electric operation. It is made clear, from an analysis of the changes involved, that electrification introduces an added hazard, while the returns from roads electrically operated make it equally obvious that it introduces, or permits the introduction of, compensating influences, with the result that the net effect of electrification on safety, favorable or otherwise, is slight — probably so slight as to be negligible.

PART IV

FINANCIAL PRACTICABILITY OF ELECTRIFICATION

401. THE FINANCIAL PRACTICABILITY OF COMPLETE ELECTRIFICATION OF CHICAGO'S RAILROAD TERMINALS

SYNOPSIS: This chapter sets forth the conditions affecting the financial practicability of any procedure having for its purpose the complete electrification of Chicago's railroad terminals. It shows the effect of electrification on the annual balance sheet of the railroads and it gives attention to various proposals which naturally suggest themselves as means whereby an unfavorable balance sheet may be overcome.

401.01 Plan of Analysis: The preceding portions of this report describe in detail the results of a smoke survey of the city of Chicago (chapter 105); they set forth a series of conclusions with reference to the necessity for the electrification of railroad terminals as a means in smoke abatement (chapter 114), the engineering features presented by the problem of electrification (chapter 208), the cost of electrification (chapter 213), and the operating results that may be expected to follow the substitution of electric operation for steam operation (chapter 301). They show that the electrification of the steam railroads now operating in the city of Chicago would be the most extensive and intricate piece of work of its kind ever undertaken; that it would introduce difficulties in installation and changes in operating procedures, the full effect of which cannot be anticipated, but that, with adequate financial backing, complete electrification could be brought about. For the purposes of this discussion it is assumed, therefore, that electrification is technically feasible. There remain to be considered only the financial aspects of the project.

It is a fact of some importance, in considering the financial practicability of the proposed undertaking, that electrification, if entered upon as a result of compulsory action, must comprehend all the 37 railroads operating within the terminal zone. Since the chief purpose of electrification is the elimination of smoke, it would be useless to require the roads of dense traffic to electrify if the roads of light traffic were to be absolved from that task. Moreover, no two of all the roads entering Chicago are entirely comparable either in the matter of operating conditions or in that of financial standing. A project that might appeal to some as an attractive investment would make no appeal to others, and a burden that might be easily borne by some would be injurious to, or even impossible of assumption by, others.

Such consideration requires that any analysis which seeks to set forth the financial practicability of electrification within the terminal zone must assume a unity of purpose. The program which is accepted as the basis of the present discussion is that which underlies the estimates of installation costs; it deals with the terminals as a whole and provides for the joint use by all roads of certain facilities. It provides a minimum installation cost and an efficient operating procedure in producing and distributing power, conditions which are essential to the purposes of this analysis.

Approaching the problem of financial practicability along broad lines, it early appears to present three aspects, each of which brings into prominence a separate set of conditions. These aspects of the problem are suggested by the following questions:

1. Can the railroads, relying upon existing sources of revenue and upon such new sources and economies as may be introduced by electrification, be depended upon to furnish the capital required for electrification?

2. Provided Question 1 is answered in the negative, can the municipality co-operate with the railroads in furnishing the capital required for electrification?

3. Provided Questions 1 and 2 are answered in the negative, can new sources of revenue, independent of any which may arise from electrification, be opened for the railroads, whereby an adequate increment of revenue may be assured for the support of the new capital required for electrification?

In preparation for a discussion of these phases of the question, it is necessary to have clearly set forth the results of the Committee's investigation respecting the necessity and cost of electrification and the estimated return which will result from electric operation.

A SUMMARY OF FACTS ESTABLISHED

401.02 The Necessity for Electrification: Electrification has been proposed as a means in smoke abatement. The extent to which the elimination of the steam locomotive and the establishment of electric operation would reduce the pollution of the atmosphere of the city may be summarized as follows:*.

1. The amount of visible smoke discharged into the atmosphere of Chicago would be reduced . . . . 20 per cent

2. The amount of solid constituents of smoke (soot, ash and fuel particles) discharged into the atmosphere of Chicago would be reduced . . . . 5 per cent

3. The amount of dust and dirt in the atmosphere of Chicago, arising from all sources, would be reduced . . . . 4 per cent

4. The volume of gaseous products of combustion discharged into the atmosphere of Chicago would be reduced . . . . 5 per cent

The facts show that the effect of electrification as a means in smoke abatement will be slight. They show that there are other fuel consuming services, especially the high pressure steam boiler service and the manufacturing service, which are more prolific contributors to the pollution of the atmosphere than the locomotive service. If the abatement of locomotive smoke is important, the abatement of smoke from these other services is more important.

401.03 Installation Cost of Electrification: The Committee's estimate respecting cost (chapter 213) covers four general phases or groups of cost. These are:

1. The cost of all new facilities, including fixed and rolling equipment, which must be applied to existing lines and terminals in order to provide for electric operation.

2. The cost of such changes in the existing railroad lines and structures as may be necessary to admit the new procedure.

3. The first cost and present value of property released for use elsewhere or abandoned.

4. The cost of new establishments to be created beyond the limits of electrification for steam operation.

The capital or construction cost† covering the four elements enumerated, on the basis of 1912, may be set forth as follows:

1. Power station	$10,302,104
2. Transmission system	1,618,693
3. Substations	2,024,736
4. Switching stations	573,073
5. Contact system	28,141,188
6. Bridge warnings	1,071,989
7. Return circuit	4,446,033
8. Elimination of inductive effects and electrolysis	996,727
9. Telephone system	272,052
10. Electric locomotives, multiple-unit equipment, work and inspection equipment	91,703,557
11. Spare parts	485,343
12. Changes in overhead structures	834,261
13. Changes in wire lines‡	2,028,007
14. Changes in signal system	6,111,407
15. Removal and re-establishment of locomotive terminals and new facilities	37,293,746
Total	$187,902,916

This represents the installation cost under the plan of the Committee and is the basis of the Committee's analysis of financial practicability. The total capital requirement is elsewhere shown (section 213.116) to be nearly a hundred million dollars in excess of this amount, but for purposes

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*See chapter 114. "The Necessity for the Electrification of the Railroad Terminals of Chicago, as a Means in Smoke Abatement."

†Estimates of the cost of electrification have been made for three distinct systems for making use of electric current, namely, the 600-volt direct current, the 2,400-volt direct current and the 11,000-volt alternating current systems (chapter 213). In order that the discussion of financial practicability may be definite, the facts respecting cost as developed for the 11,000-volt alternating current system are used. This does not forecast an opinion as to the relative desirability of the different systems.

‡Wire lines are not all owned by the railroad companies. While the cost of changing them is a proper charge against electrification, the Committee does not undertake to say who shall be responsible for the cost.

of this analysis this excess cost must be carried forward as indeterminate.*

401.04 Net Installation Cost: To obtain the net cost of electrification, it is necessary to deduct from the gross cost, as set forth in the preceding section, the salvage on property abandoned and released from local transportation service. The facts involved are as follows:

1. Cost of electrification, including all details necessary to make up the new establishment, and all changes in existing facilities made necessary by the introduction of new equipment but not including any general revision of terminals	$187,902,916
2. Net salvage (section 213.139)	9,775,686
Net cost	$178,127,230

The preceding statements make clear three points of importance:

> 1. That the amount of money which the railroads will probably find it desirable to expend in electrification and in betterments precipitated thereby is $274,440,630
>
> 2. That the amount which must be available to satisfy the requirements of a minimum plan as outlined by the Committee, excluding all precipitated costs, is $187,902,916
>
> 3. That, assuming the railroads to be going concerns having needs arising from growth in many directions which will absorb released equipment and salvage values, the minimum demand on the investment fund due to the project of electrification is reduced to . . . $178,127,230

401.05 Abandoned Property Cost: A program of electrification, such as is under consideration, involves the abandonment of certain terminal property which is now used by railroads and which, in the absence of electrification, will continue to be so used as long as the terminals are operated by steam locomotives. This means the dissipation of a certain amount of existing assets. The engineering estimates of terminal property to be abandoned are as follows:†

Terminal property to be abandoned (not chargeable to capital)	$2,317,957

While it is true that the property to be abandoned to make room for an improvement should be included in the cost of the improvement, it is not a capital charge. It is lost to the railroads. It cannot be charged to new construction nor can it be retained in the old capital account. It must be charged to profit and loss, or be carried as a deferred asset and written out of the accounts by annual charges against subsequent revenues. The latter course will be followed, it being assumed that such charges will be made over a period of ten years.

401.06 The Return on the Investment:‡ In forecasting the financial practicability of any undertaking that involves the investment of free capital, it is necessary to estimate prospective revenues and expenses, and to consider the value of benefits likely to accrue. The more important possible sources of benefit to be expected from the electrification of Chicago's railroads are:

> 1. Direct money return through reduced expense in operation.
>
> 2. Increased capacity of terminals.
>
> 3. Return in the form of higher quality of service.
>
> 4. The intensive use of property at present utilized for railroad purposes only.
>
> 5. The extension of electric service from a source made necessary for traction purposes to all purposes for which such service is required by the railroads.

A detailed discussion of these several sources of possible return has already been presented. For the present purpose they may be grouped under two general heads, the first to include those items which can be given a money value, and the second, those which must remain indeterminate in value. The determinate factors are all embraced by the operating results.¶ A summarized statement of the return to be expected from the electrification of Chicago's railroads may be set forth as follows:

Net annual saving in operation (11,000-volt a. c. system)	$2,336,693+	
Value of indeterminate benefits	Indeterminate	
Total return		$2,336,693+

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*Attention has been directed elsewhere (section 213.111) to the fact that the estimates of the Committee as herein set forth are not the full costs which will be imposed by electrification. The total demand for capital has been set forth (section 213.116) as follows:

1. Net cost of electrification, including all details necessary to make up the new establishment and all changes in existing facilities made necessary by the introduction of new equipment, as defined by the plan of the Committee (section 213.139)	$178,127,230
2. Added costs to cover departures from the Committee's plan, deemed necessary by railroads interested, and to cover betterments precipitated by electrification	96,313,400
Total capital requirement	$274,440,630

The added costs to cover departures from the Committee's plan, which may be deemed necessary by railroad officials, and to cover betterments precipitated by electrification are not carried into the analysis which follows, because:

1. So far as they arise from an extension of plans for electrification, they are not paralleled by the formulated statement of operating results; these, as presented, are limited by the Committee's plan.
2. So far as they are non-related to electrification itself but are costs which are precipitated thereby, they are not a charge against electrification.

For the purposes of the discussion which follows, therefore, a specific value for these added costs cannot appear. They can only be referred to as indeterminate.

† See Chapter 213.

‡ A full discussion of the results of electrification which will accrue to the railroads will be found in section 301.17 of this report.

¶ See Chapters 301 to 303, inclusive.

FINANCIAL PRACTICABILITY

401.07 The Test of Financial Practicability: The test of the financial practicability of any proposal that involves the investment of free capital lies in the willingness on the part of those who control such capital to make the investment. It must be assumed that those who control the capital possess ordinary business intelligence and integrity. Whether appeals for credit are made to individuals, to established corporations, to the government, or to an organization that makes use of all three of these agencies, the prospectus on which the appeal is made must set forth reasonable means for expectation of financial success. The particular proposal under consideration is the electrification, within prescribed limits, of all railroads which enter or operate within the city of Chicago, such electrification being an essential part of a general plan for smoke abatement within the city. Can this proposal be organized in such a way as to make the program financially practicable?

401.08 The Credit of the Railroads: It will be assumed that the combined credit of the 37 railroads which would be affected by the proposal to electrify is adequate to carry the cost of electrification, but this alone does not warrant the assumption that the railroads are able to finance the project. Some of the railroads concerned are continental lines. Together they reach from the Atlantic to the Pacific and from the Great Lakes to the Gulf. No single locality is responsible for the enormous credit controlled by these properties and hence no single locality is at liberty to claim exclusive benefit of that credit.

The various railroads are interested in the uniform development of the territory in which they operate. This is essential for the protection of their transportation interests and the railroads are consequently debarred from showing local preference. Nor is it proper for a municipality to claim for itself more than a just and reasonable proportion of the aggregate credit of the railroads upon which it depends for transportation service. Even if it did present such a claim and passed an ordinance for its expression, it is scarcely conceivable that the courts would grant their approval. The railroad credit belongs wherever the railroad goes. Not all the railroads of Chicago are Illinois corporations, and some cannot issue additional securities either in stocks or bonds without first having the approval of other states.*

It seems reasonable, therefore, to assert that the existence in the hands of railroads of potential credit adequate to meet the cost of electrification is no ground for assuming that the railroads are able to furnish the required capital.

Several other pertinent observations are suggested in this connection:

1. The credits of the individual railroads, the properties of which make up the Chicago railroad terminals, differ greatly. Some have high credit and could secure funds for almost any project which their managements might care to propose; others must prove the profitable character of a particular project before underwriters would consider the placement of their securities; others would find it difficult to borrow on reasonable terms even if the particular project for which the funds were sought promised some return; and still others are in the hands of receivers, their administrative function being performed by the courts. These facts cannot be overlooked in estimating what portion of the potential credit of the railroads is available for the purpose of electrification.

2. Certain railroads making up the Chicago terminals operate entirely within the prescribed zone, while for others the great predominance of traffic lies outside the terminal limits. There is more to this contrast than is implied by the fact that some of the roads involved are switching roads while others are long-haul freight and passenger roads. Complete electrification, from a financial point of view, would affect but a relatively small part of the fixed investments of some roads, while for others it would require practically the rebuilding of the property. This fact is of great importance in measuring the credit available for the project of electrification. The question to be asked is not, "What is the credit of a railroad," but, "What is the credit of a road in view of the particular project under consideration?" The road whose credit stands high when considered in relation to its capital investment; its revenues, its strategic position or to a normal program of investments, may fail entirely if called upon to support an improvement that involves the rebuilding of its property.

3. Electrification is a matter which may present greater advantages in connection with certain classes of service than with other classes of service; for example, the electrification of a railroad having a large suburban business would be more effective in developing opinion favorable to the railroad concerned than the electrification of a road, the activities of which are wholly those of freight switching yards. Upon this basis, the railroads which operate the railroad terminals of Chicago

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* For example, the Chicago & North Western Railway cannot issue additional securities without the consent of the state commissions of Illinois, Wisconsin, Michigan and Nebraska.

do not have the same relative interests. A few only depend upon passenger traffic within the city limits for any considerable amount of their revenue; a larger number derive passenger revenue within the terminals from the movement of through passengers only; while other roads perform little or no passenger service. These varying conditions assume considerable significance, since they make apparent the fact that the anticipated increase in revenue resulting from electrification must be estimated on a different basis for each railroad concerned.

4. The extent to which individual railroads have recently made large capital expenditures for terminal improvements, track elevation and enlargement of facilities in Chicago, and the extent to which they are committed to further expenditure for these purposes must have a material bearing on their ability to make expenditures for new projects. It is, therefore, necessary to place the demand for capital on account of electrification in comparison with other classes of demands before concluding that the credit of the roads concerned can furnish the required capital.

5. Increased capitalization may affect adversely outstanding securities, the interests of security holders and in turn the credit of the corporation. Its tendency is to increase the cost to the corporation of subsequent borrowings.

401.09 Electrification as a Railroad Investment: It is now possible to take up the first of the three questions which it is the purpose of this discussion on financial practicability to answer. Can the railroads operating within the terminal zone of Chicago be relied upon to furnish the required capital for electrification?

The annual charges which must be borne by the project of electrification, if it is to be justified as a sound business investment on the part of the railroads, are taxes, interest on capital, depreciation charges and deferred charges on abandoned property. Each of these charges will be considered.

401.10 Charges to Cover Taxes: The extent to which the new materials and equipment making up the facilities of electrification will involve the railroads in increased charges for taxes, constitutes a matter concerning which widely varying expert opinions have been expressed. The complications of the problem are such that the Committee presents no numerical estimate. The increased amount, therefore, which the railroads would pay in taxes, in 1922 and thereafter, assuming the Chicago terminals to be completely electrified, must, for the purposes of this report, remain indeterminate.

401.11 Interest Charges: The rate of interest required will vary with the credit of the enterprise and the state of the money market. If the credit used to raise the needed capital is railroad credit and if the project is to proceed according to the program of construction set forth by the estimates of this report, five per cent is not too high a rate by which to compute the annual interest charge.

Five per cent of $178,127,230 = $8,906,362

401.12 Depreciation Charge: The term "depreciation," as herein used, refers to the diminution which takes place in the value of a facility in spite of the amount expended upon it in repairs. As defined by the Interstate Commerce Commission, it covers:

1. The losses suffered through the current lessening in value of tangible property from wear and tear (not covered by current repairs).

2. Obsolescence or inadequacy resulting from age, physical change, or supersession by reason of new inventions and discoveries, changes in popular demand or public requirements.

3. Losses suffered through destruction of property by extraordinary casualties.

It is in this broad sense that the term is herein used. In further consideration of this element of cost, the fact should be borne in mind that maintenance of the new establishment incident to electrification has been already provided for (chapter 301).

All the property involved in the electrification project, except real estate, is subject to depreciation, but that does not mean that electrification should bear a depreciation charge computed on all that property. To a limited extent the units of property which make up the physical fabric of electrification are replacements of units of property already productive of revenues under steam locomotive operation. To the extent of these replacement units, the revenues which already exist, not the new revenues to be opened up by electrification, should bear the depreciation charge. The electrification project should be charged only with the depreciation on property that is new in kind. For example, the power station, both its buildings and equipment, the substations and the transmission lines are peculiar to the electrification project, and for that reason the depreciation on them should be covered by electrification revenues; but the depreciation on alterations to buildings and bridges, or changes in wire lines which are merely subject to modification in form to adapt them to new requirements, should be charged against revenues derived from pre-existing sources. When replacement units required by electrification are of greater cost than the steam operating units replaced, as in the case of re-located terminal facilities for the care of steam locomotives, the depreciation on the excess cost may properly be charged to electrification.

Upon this basis, the items which are subject to a depreciation charge and the corresponding installation costs, are as follows:

1. Power station	$10,302,104	
2. Transmission system	1,618,693	
3. Substations	2,024,736	
4. Switching stations	573,073	
5. Overhead contact system	28,141,188	
6. Bridge warnings	1,071,989	
7. Return circuit	4,446,033	
8. Prevention of inductive effects and electrolysis	996,727	
9. Telephone system	272,052	
10. Electric locomotives, multiple-unit equipment, work and inspection equipment	91,703,557	
11. Spare parts	485,343	
12. Removal and re-establishment of steam locomotive terminals	37,293,746	
Total		$178,929,241

The items which are not subject to a depreciation charge, and the amounts involved, are as follows:

1. Alterations to buildings and bridges	$ 834,261	
2. Changes in wire lines	2,028,007	
3. Changes in signals	6,111,407	
Total		$8,973,675*

Methods of accounting by which the depreciation charge is made vary greatly. As applied to public utilities, it is sometimes taken as a percentage of the gross receipts. It is most frequently based upon installation cost or, when the amount of this is unknown, upon an appraised replacement value. For the present purpose, the charge to depreciation may be based upon the estimated installation cost.

The value of the depreciation factor necessarily depends upon the manner in which it is applied, whether, for example, as a fixed percentage of the installation cost, applied year after year, or as a percentage applied to the depreciated values as reduced by the accountings of successive years. Whatever the method, the process of fixing the rate must ultimately refer to two fundamental facts, namely, the probable life of the facility and its residual value at the end of that period, either for use in secondary service or as scrap. The determination of these facts constitutes the most difficult aspect of the problem of depreciation. In the further discussion of this aspect of the matter, it will be convenient to segregate the various details of the electrification establishment as already set forth, into groups, the several elements of which are more or less similar in character. The result of such a process is as follows:

Group I:		
Power station	$10,302,104	
Substations	2,024,736	
Switching stations	573,073	
Prevention of inductive effects and electrolysis	996,727	
Spare parts	485,343	
		$14,381,983
Group II:		
Electric locomotives, multiple-unit equipment, work and inspection equipment		$91,703,557
Group III:		
Transmission system	$ 1,618,693	
Overhead contact system	28,141,188	
Telephone system	272,052	
Bridge warnings	1,071,989	
Return circuit	4,446,033	
		$35,549,955
Group IV:		
Removal and re-establishment of steam locomotive terminals		$37,293,746
Total		$178,929,241†

Group I includes chiefly the power station and substations. The estimates cover an amount of real estate which is relatively so small as to be negligible. They cover the cost of buildings which may be assumed to have a comparatively long life and a correspondingly low rate of depreciation. They cover electric equipment which is not different in character from that in use by utility corporations in many cities. This group probably represents the most stable portion of the electric establishment. It has been determined to accept a flat rate of four per cent per annum as applicable to the entire cost of this group. This implies that a lower value would normally be taken for buildings and a higher value for machinery. Applied each year to the installation cost, four per

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* These values are based upon the plan of the Committee. The cost estimated by the railroads is in excess of amounts here given (chapter 213).

† This value is based upon the plan of the Committee. The amount which is to be depreciated under the estimates of the railroads will be in excess of that given (chapter 213).

cent will, if credited to a sinking fund capable of earning five per cent per annum, produce in 15 years 85 per cent of the actual installation cost, and in 17 years the original cost. Upon the basis set forth, the annual charge for the depreciation of the facilities of Group I will be:

Four per cent of $14,381,983 = $575,279

Group II represents rolling equipment, which includes electric locomotives for switching, freight and passenger services, multiple-unit equipment and certain repair equipment. The world's experience with such equipment is thus far limited, and those best acquainted with the subject hesitate to say how long a given installation, though well maintained, will serve the purpose for which it was designed. Considered merely as machines designed to perform certain definite functions under prescribed conditions, electric rolling equipment may very properly be credited with a longevity equal to that of most other machinery; but with electric locomotives and motor cars, long life is endangered by many influences, especially by the appearance of new ideas and improvements. Attention has already been called to the experimental aspect of an undertaking so extensive as that which is involved by the electrification of Chicago's railroad terminals, where many details of the whole procedure must assume forms which are tentative. The whole science and art of electrification is progressing so rapidly that the engineer who makes his specifications, in the light of present-day knowledge, in the expectation of meeting the requirements of an enterprise which is to become operatively effective in 1922, cannot be sure that the establishment for which he provides will be serviceable in 1937, 15 years after the completion of the initial investment. Such considerations not only justify but require the assumption of a comparatively short life. The Committee assumes that the facilities of this group should be subject to a depreciation charge of not less than five per cent, which, applied each year to installation cost, will, if credited to a sinking fund capable of earning five per cent per annum, produce in 13 years 88 per cent of the installation cost and in 15 years the original cost.

Upon the basis set forth, the annual charge for the depreciation of the facilities of Group II will be as follows:

Five per cent of $91,703,557 = $4,585,178

From this amount there must be deducted a sum equal to that which presumably is now being charged to cover the depreciation of steam locomotives and cars released. The first cost of such equipment released has already been set forth (chapter 213). It amounts to $20,480,944. The actual amounts which are being charged off by the railroads for the depreciation of such equipment vary greatly. It is believed that comparable results will be secured by assuming four per cent of first cost as the rate of depreciation on such equipment. The credit, therefore, is:

Four per cent of $20,480,944 = $819,238

The accounting for the depreciation of the facilities of Group II, arising from electrification, is:

Annual charge to depreciation, to cover new rolling equipment	$4,585,178	
Depreciation of rolling equipment released	819,238	
Net annual depreciation of rolling equipment		$3,765,940

Group III covers transmission lines, overhead contact system, the return circuit (bonding) and other details comparable with these. This group, while representing facilities different in character from those included in Groups I and II and while subject to different influences, stands, on the whole, substantially upon the same basis. The longevity of the bonding is a function of the life of the track, and the rebuilding or replacement of track will necessarily involve reconstruction of the bonding, however well maintained the existing system may be. The overhead contact system, while designed in accordance with the highest standards recognized by present-day practice, may be entirely inadequate to meet requirements which may be introduced by changes in related facilities made possible or necessary by improved practice. The facilities of this group should, therefore, be subject to a depreciation charge of not less than five per cent. Upon this basis the annual charge for the depreciation of the facilities of Group III will be:

Five per cent of $35,549,955 = $1,777,498

Group IV covers removal and re-establishment of steam locomotive terminals, less the present value of facilities abandoned. Under this caption are included all items which enter into the cost of the new transfer establishments which, for each road, mark the termination of the electrified trackage. Of this group, 15 per cent of the cost covers land and grading, which is not regarded as subject to depreciation; 32 per cent covers the cost of buildings, including transfer stations, roundhouses, locomotive inspection sheds and the equipment of these, which, because of the use to which they are to be put, should be subject to a relatively high depreciation charge; the remaining 53 per cent covers new tracks needed in transfer yards, overhead contact system and other electric facilities needed for the operation of such tracks, ash-pits, coaling stations, and turntables, many of which facilities must be subject to a very high depreciation charge. An extension of electric operation by any road to include a full operating division would at once render intermediate transfer establishments unnecessary. The Committee has assumed that a depreciation factor of five per cent may properly be applied to the group.

Upon the basis set forth, the annual charge for depreciation of the facilities of Group IV will be:

Five per cent of $37,293,746 = $1,864,687

From this amount there must be deducted a sum equal to that which presumably is now being charged to cover the depreciation of steam locomotive terminal facilities released. The first cost of terminal facilities released has been set forth elsewhere (chapter 213). It amounts to $3,502,530. That the credit may be comparable with the charge, the depreciation rate is taken as five per cent of the first cost. The credit, therefore, is:

Five per cent of $3,502,530 = $175,126

The accounting for the depreciation of the facilities of Group IV, arising from electrification, is as follows:

Annual charge to depreciation, to cover new facilities	$1,864,687	
Depreciation of facilities released or abandoned	175,126	
Net annual depreciation		$1,689,561

On the basis set forth by the preceding paragraphs, the annual depreciation charge, by groups, may be presented as follows:

Group I	$ 575,279	
Group II	3,765,940	
Group III	1,777,498	
Group IV	1,689,561	
Total		$7,808,278

The depreciation charge as thus determined is equivalent to that which would result from a flat rate of 4.36 per cent applied to the entire cost of electrification under the plan of the Committee, namely, $178,929,241.

401.13 Charges for Abandoned Property: A fourth charge against the project of electrification is the restoration of dissipated assets resulting from the substitution of electric for steam operation. The manner in which this is to be attained, so far as it affects the railroads, is not important for the purposes of this report, but the rapidity with which this replacement is to be accomplished and the date when the charge begins are of importance. In order to submit an accounting statement in concrete form, it will be assumed that $2,317,957[*] (chapter 213) of abandoned property will be replaced by an annual charge of $231,796 for ten years, and that accrual for this charge should begin immediately on the close of the construction period.

401.14 The Accounting Statement: An accounting statement from which one may conclude whether or not reliance can be placed upon the credit of the railroads to furnish the free capital required for carrying through the electrification project, may now be submitted. It shows the annual charges and the revenues properly credited to electrification, as follows:

ACCOUNTING STATEMENT FOR DISCLOSING THE FINANCIAL PRACTICABILITY OF ELECTRIFICATION [†]

I. *Annual Charges:*		
1. Interest (section 401.11) . .	$8,906,362	
2. Depreciation (section 401.12) .	7,808,278	
3. Replacement of dissipated assets (section 401.13)	231,796	
4. Indeterminate charges (chapter 302 and section 401.10) . .	....	
Total charges		$16,946,436+
II. *Annual Revenues:*		
1. Increase in net revenues (section 301.16)	$2,336,693	
2. Indeterminate benefits (chapter 302)	....	
Total credits		$ 2,336,693+
Balance, annual deficit on investment		$14,609,743 ±

The conclusion from the above accounting statement is clear. The railroads cannot be relied upon to furnish the necessary capital for this

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[*] This value is based upon the plan of the Committee, which constitutes a minimum plan. The amount of property to be abandoned under the estimates of the railroads would be in excess of the amount indicated.

[†] This statement is based upon the plan of the Committee. The showing would be entirely different under the estimates of the railroads.

electrification project. It will be necessary either to place larger revenues to the credit of electrification or to look elsewhere for the capital.

401.15 Electrification as a Municipal Investment: Attention may now be turned to the second question which lies in the analysis of financial practicability. If the railroads cannot be relied upon to furnish the necessary capital for carrying through the electrification of Chicago's terminals, can the municipality co-operate with the railroads in furnishing the required capital?

In view of the fact that the purpose of electrification is to secure a reduction in the amount of smoke which enters the atmosphere of the city, it would seem proper that the credit of the municipality should, if necessary, supplement the credit of the railroads. The situation is analogous to the use of the collective credit of the citizens of Chicago for obtaining pure water or for the construction of an adequate drainage system. In these cases the interests involved are common interests and the costs are consequently common costs. In the case of electrification, however, there is a special as well as a general interest, and to the extent of the general interest only would the municipality be warranted in making use of public credit for the purpose of electrification.

The organization of the enterprise on the basis of joint use of public and railroad credit opens up a broad field of constructive finance. The Committee assumes, however, that it would be useless to submit definite suggestions along this line, since the constitution of the state of Illinois makes it impossible for the municipality to use its credit in this manner. In a separate section of the Constitution of 1870, the following article provides that:

> "No county, city, town, township, or other municipality shall ever become subscriber to the capital stock of any railroad or private corporation, or make donation to or loan its credit in aid of such corporation, provided, however, that the adoption of this article shall not be construed as affecting the right of any such municipality to make such subscriptions where the same have been authorized under existing law by a vote of the people of such municipalities prior to such adoption."

This provision of the constitution has been construed many times by the Supreme Court of the State of Illinois and by the United States Supreme Court, and the general trend of these constructions supports a strict interpretation of the language quoted. Moreover, even though it were possible to distinguish between the cases passed upon by the courts and the use of municipal credit for the elimination of smoke on the ground that the end to be attained is a public purpose, no practical result could follow, at least for some years to come, for the reason that it would be impossible for the city, under present constitutional and statutory limitations, to raise the necessary funds without the issuance of bonds beyond the authorized limit.

Electrification as a result of municipal participation is, therefore, impracticable under present conditions.*

401.16 Electrification Supported by Traffic Arbitraries: A third suggestion for the financial organization of the project of electrification concerns the practicability of opening new sources of revenue to the railroads through the application of an arbitrary tax on terminal traffic which will serve to support the new capital required for electrification. Such an arbitrary may be applied in either of two ways:

1. It may be added to the previously existing tariff as a charge to be paid by those who make use of Chicago railroad facilities. An arbitrary thus applied would become, in effect, a local charge.
2. It may be deducted from the gross revenues of the traffic coming in or going out of the city before distribution is made to lines which extend their operation outside the city. An arbitrary thus applied would become, in effect, a tax on Chicago traffic for the support of a local improvement.

Either of these methods will serve the purpose of electrification. The difference between them pertains to the incidence of the burden. According to the first method, the $14,600,000 which will be required annually to support the new investment will be collected from Chicago passengers, whether suburban, local or through, and from Chicago shippers whether consignors or consignees. Except in the case of goods for which Chicago has a monopoly as against other cities, it will not be possible to shift the burden of this arbitrary. Chicago dealers cannot raise their prices because of this increase in passenger or freight tariffs.

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*The possibility of making available the common credit of the citizens through the creation by legislative enactment of a special governmental unit for the administration of the citizens' interest within the electrification zone, raises many questions of procedure, which are assumed to be outside of the Committee's province and consequently have not been considered.

By the second method, the burden of the arbitrary will be thrown wherever the revenue on Chicago traffic accrues and will be spread in proportion to the length of haul of such traffic, but this will not prevent the burden from becoming an indirect tax upon Chicago business since it will operate to divert into other channels traffic which normally would come to Chicago.

The possible effect of arbitraries, if levied upon the commercial and industrial activities of the city, is a matter presenting many details and is one which has not been studied by the Committee.

401.17 Conclusions Concerning Financial Practicability: The preceding discussion justifies the following general conclusions:

1. The complete electrification of the railroad terminals of Chicago as a betterment to be brought about by the railroads through the investment of free capital is, under present-day conditions, financially impracticable.

2. Any procedure designed to bring about the complete electrification of Chicago's railroad terminals which is based upon a financial program involving municipal cooperation is, under present-day conditions, impracticable.

3. Any procedure designed to bring about the complete electrification of Chicago's railroad terminals which is based upon the application of an arbitrary to traffic of Chicago will constitute a tax which must be borne by the business interests of the city. The practicability of such a tax is a matter which has not been studied by the Committee.

4. The preceding conclusions apply to the complete electrification of Chicago's railroad terminals. The financial practicability, under present-day conditions, of electrification as it might be applied to individual roads or to a single service of individual roads, is a matter which has not been investigated by the Committee and concerning which no opinion is expressed.

PART V

SUMMARY OF CONCLUSIONS WITH REFERENCE TO THE ELECTRIFICATION OF RAILROAD TERMINALS

501. THE NECESSITY, TECHNICAL FEASIBILITY AND FINANCIAL PRACTICABILITY OF ELECTRIFICATION

SYNOPSIS: This chapter summarizes the Committee's findings with reference to the necessity for electrification as a means in smoke abatement; it reviews the evidence which has been presented concerning the technical feasibility of complete electrification; and it restates the facts concerning the financial practicability of such an undertaking.

501.01 The Purpose of the Committee: The purpose for which the Committee was organized was early defined as embracing a determination as to:

1. The necessity of changing the motive power of steam railroads to electric or other power.
2. The mechanical or technical feasibility of such a change.
3. The financial practicability of such a change.

The conclusions reached with reference to these three questions may now be set forth.

501.02 The Necessity of Changing the Motive Power of Steam Railroads to Electric or Other Power: In its efforts to reach a just decision with reference to the necessity of changing the motive power of steam railroads to electric or other power, the Committee, aided by the active co-operation of many different agencies, has concluded an elaborate research concerning the consumption of fuel and the origin of smoke in the city of Chicago. This research has covered coal deliveries, reshipments of coal and changes in amounts of coal stored within the Area of Investigation during the calendar year of 1912. The statistics gathered show the origin of all fuel delivered and the service in which it was used.

The investigations have shown that the various activities of Chicago require the use of enormous quantities of fuel; that the per capita consumption is greater than that of most other cities; that the amount consumed by steam locomotives is less than a third of that burned under high pressure steam boilers, one-half of that which is consumed in domestic heating, much less than that used in manufacturing fires and but a small fraction (12 per cent) of the total burned by the combined fuel consuming industries of the city.

The Committee has analyzed the characteristics of Chicago's fuels and considered the means which may be best employed in utilizing the city's fuels; it has shown that Chicago's problem in smoke abatement is difficult, because the fuels tributary to Chicago, being high in volatile matter, are of a class usually designated as "smoky."

The Committee has studied the composition of the atmosphere of Chicago, the effect upon its purity of the smoke discharged and the extent to which it is polluted by foreign material not of fuel origin.

The investigation has shown that smoke in the atmosphere presents three principal aspects, namely, visible properties, solid constituents and gaseous products. It has shown that hitherto emphasis in smoke abatement has been given to smoke in its visible aspects, whereas it appears that the solid constituents of smoke are more important agencies affecting atmospheric pollution. It has shown also that gaseous products of combustion are important polluting agencies only with reference to their sulphurous constituents, and that the amount of sulphur in smoke is dependent upon the amount of fuel consumed and may be accepted as being independent of the particular service in which it is burned.

It has been made apparent that no single fuel consuming service nor single locality is alone responsible for the smoke of Chicago, but that all fuel consuming industries and all localities produce smoke.

The research has demonstrated that the elimination of the steam locomotive from Chicago will involve the electrification of the city's railroad terminals, since there is no other known form of motive power which can be accepted in all the services of the terminals as a substitute for the steam locomotive. It has further demonstrated that electrification implies increased capacity of existing electric generating stations or the introduction of new stations which must be steam driven, either of which expediencies means new sources of fuel consumption and smoke; and that the net effect of electrification upon atmospheric pollution will be represented by the difference between the amount of smoke now discharged by steam locomotives and the amount which, under electrification, will be discharged from the electric generating stations.

The study has shown that the elimination of all steam locomotives from the city of Chicago would reduce the amount of visible smoke entering the atmosphere by approximately one-fifth the present amount; that it would reduce the dust and dirt content and the sulphurous content of the atmosphere of the city as a whole by a relatively small amount; and that as a consequence the locomotive is not at present a controlling factor as a source of atmospheric pollution.

The observations of the Committee, confirmed by the records of Chicago's department of smoke inspection, are to the effect that great progress has in recent years been made in reducing locomotive smoke and that maximum results have not yet been obtained. Hence it cannot be urged that, with reference to smoke abatement, the steam locomotive service is an unmanageable service.

The investigations do not support the contention that elimination of steam locomotive smoke is a necessary next step in the city's progress in smoke abatement. They show, on the contrary, that before the complete elimination of steam locomotive smoke can be regarded as imperative, smoke from all existing sources should be reduced to a minimum, and that to this end some of the city's more obvious undertakings should be:

1. The extension of the operations of Chicago's department of smoke inspection over the entire area of the city, instead of confining them to a selected portion of this area.
2. A material extension in the character of the city's activities in smoke abatement to the end that they may include such work of research and instruction as will make the city co-operatively helpful to coal consumers in the development of a constructive policy in smoke abatement.
3. A reduction to a minimum of all smoke discharged within the city, whatever its source.
4. Recognition by the city that smoke is not the only source of atmospheric pollution, that the dirt of the atmosphere is in part the result of imperfect cleaning processes, and that the whole problem of municipal house-cleaning must be developed to a high state of efficiency before the complete elimination of the steam locomotive for the purpose of reducing atmospheric dirt can be justified.

The Committee is not unmindful of the advantages which, in addition to those which would attend the abatement of smoke, would accrue through the electrification of Chicago's railroad terminals. It is not unmindful of the desire of certain portions of the traveling public to bring about the electrification of particular services of individual roads. Its problem, however, as originally outlined was that of determining the necessity for the electrification of all roads and all services within the city as a means in abating the smoke of the city. The conclusion of the Committee, based upon the facts of record, is to the effect:

> That the complete elimination of steam locomotives from the railroad terminals of Chicago, as a means in smoke abatement, is not, under present-day conditions, necessary.

501.03 The Mechanical or Technical Feasibility of Electrification: In its study of the technical feasibility of electrification the Committee has made a world review of undertakings involving the electrification of steam railroads. It has studied the terminal situation in Chicago for the purpose of establishing a relation between that which has already been accomplished and that which will need to be done if Chicago's railroad terminals are to be electrified. It finds that experience elsewhere has demonstrated that:

1. Trains of any weight can be hauled electrically at any necessary speed, provided sufficient electric power can be conveyed to the train motors.

2. Where appliances can be properly installed and maintained electric traction is reliable.

3. Electrification introduces an added hazard incident to railroad operation, but to what extent is indeterminate. The returns from railroads electrically operated make it clear, also, that it introduces compensating influences which apparently equalize whatever additional hazard electric operation may involve.

It finds also that electrification has proceeded, with reference to different railroad services, along lines as follows:

1. Electrification has most frequently been employed in operating suburban passenger service.

2. It has been used for all passenger service in connection with the intensive development of great passenger terminals where underground operation has been involved.

3. It has been used for both freight and passenger operation in tunnels.

4. It has been applied to sections of through lines of route to improve operation of both freight and passenger service on difficult grades.

5. It has been applied to sections of through route lines in anticipation of operating economies through the utilization of water or other relatively inexpensive centralized power.

6. It has been employed by a single railroad in this country in the operation of three switching yards, the work of which must still be regarded as being in an experimental stage.

The demonstrated facts disclose the existence of a wide gap between that which has been accomplished and that which must be done to meet all the various conditions presented by the proposed electric operation of the Chicago terminals. This is because:

1. Progress in the development of electric installations has thus far not resulted in the adoption of standards governing the electric system to be employed, the design of equipment or the methods of operation. The electrification of Chicago's railroad terminals would, therefore, involve definite decisions with reference to many features for which there are as yet no approved standards.

2. The Chicago terminals involve the interests of many railroads, whose joint action is essential to a satisfactory technical development of the problem. The fabric of electrification must be designed to meet the requirements of the entire terminal rather than those of any single road.

3. The Chicago terminals include both railroads having their entire mileage within the city and railroads operating continental lines and possessing a terminal interest only in the city. Electrification of the lines wholly within the city would affect their entire trackage and would mean, practically, reconstruction. Electrification of through lines implies the development of a local improvement. The methods by which roads sustaining widely diversified interests would seek to accomplish their work of electrification would involve technical as well as business procedures.

It has been shown to be technically feasible for each individual road in Chicago, for any group of such roads or for all such roads acting in common to provide for the generation and distribution of power to predetermined points of consumption along the rights-of-way of railroads.

It has been shown to be technically feasible for each individual road in Chicago, for any group of such roads or for all such roads acting in common to secure through purchase the energy they require, delivered at predetermined points of consumption along the right-of-way.

Electrification implies the establishment of some form of contact system along each line of railroad track, whereby energy may be delivered to the rolling equipment. A study of track and operating conditions reveals the following facts:

1. A limited mileage of track in Chicago (approximately one per cent of the total) cannot be equipped with any system of contact which could be accepted as satisfactory for the terminal as a whole. The electrification of this trackage as a part of a general system of electrification is, therefore, assumed to be not technically feasible.

2. While the third rail system of contact might be extensively used in Chicago, there are, at intervals throughout a considerable percentage of the total trackage, conditions which would make difficult the use of this form of contact. The third rail is applied with difficulty wherever special track work abounds, where street and railroad crossings occur at frequent intervals, and in switching yards. In locations where employes must be between or must cross tracks, as in freight yards, it constitutes a physical obstruction which is highly objectionable. For these reasons the third rail is not considered feasible for general use in the Chicago terminals.

3. The facts developed show that any form of overhead contact which can be placed high enough above the rail to give the clearance necessary to

> permit men to ride and perform necessary duties on the tops of freight cars is not objectionable from a technical point of view. The application of an overhead contact system to the terminals of Chicago will, however, require the contact wire to be lowered in many places in order that it may pass under structures presenting minimum clearance. The great number of points at which the contact wire must be lowered will require the installation of many warning devices or the enforcement of rigid rules governing the presence of trainmen on tops of cars.

The adoption of an overhead contact system will permit the use either of the so-called high voltage direct current or of alternating current at much higher voltage. The purposes of electrification can be accomplished through either of these means.

The Committee finds that the use of direct current by the railroads of Chicago would involve careful designing and construction to avoid the introduction of difficulties arising from electrolytic action. While the questions of standards to be observed in this respect are as yet undetermined, it is believed that difficulties arising from this source are not such as to affect the feasibility of any general plan of electrification which may involve the use of direct current.

It finds that the use of alternating current by the railroads of Chicago would involve careful designing and construction to avoid inductive interferences with existing telephone and telegraph circuits. While the means to be employed in preventing and overcoming such disturbances are not yet standardized, it is believed that the difficulties to be experienced from this source are not such as to affect the practicability of any general scheme of electrification involving the use of alternating current.

The general conclusion of the Committee, concerning the technical feasibility of complete electrification of Chicago's railroad terminals, is to the following effect:

> 1. The launching of such an undertaking, to be participated in by all the railroads at practically the same time, will involve a large amount of experimentation.
>
> 2. The problem of contact design, when considered in relation to normal railroad operation, presents many difficulties. A limited amount of trackage in the Chicago terminals is so located that it has been found impracticable to equip it with any form of contact system. Operation over such trackage subsequent to electrification will need to be conducted by some form of self-propelled unit or there must be some rearrangement of tracks. The difficulties imposed at numerous points by insufficient clearance of overhead structures will, under the plan of the Committee, be met by the installation of warning devices or the enforcement of regulations governing the presence of trainmen on tops of cars.
>
> 3. The technical difficulties to be met and overcome in bringing about the complete electrification of Chicago's terminals will, through the general development of the art, diminish year by year.

501.04 The Financial Practicability of Electrification: In its consideration of this aspect of its problem, the Committee has made a detailed study of the work which will be necessary to bring about the complete electrification of Chicago's railroad terminals. It has fixed the limits to be observed by each railroad in the development of electric operation. It has determined the amount of equipment which will be required, has designed contact systems, and has proceeded, in all important respects, by methods which would be necessary if electrification had been definitely determined upon. By such a process the cost of complete electrification has been estimated.

Studies have also been made to determine the operating results which would follow complete electrification of Chicago's railroad terminals, in order that profits and other forms of benefit which might be derived from such a change may be known.

With the data thus obtained, concerning the extent of the investment which must be made and the returns which may be expected as a result of such an investment, the Committee concludes that:

> The complete electrification of the railroad terminals of Chicago as a betterment to be brought about by the railroads through the investment of free capital is, under present-day conditions, financially impracticable.

Careful consideration has been given to proposals contemplating municipal co-operation with the railroads in bringing about complete electrification of their terminals, with the conclusion that:

> Any procedure designed to bring about the complete electrification of Chicago's railroad terminals, which is based upon a financial program involving municipal co-operation is, under the present state constitution, impossible.

The Committee has considered whether the funds necessary for the support of the investment which must be made to bring about complete electrification might not be provided through the application of an arbitrary charge or tax whereby the railroads might develop added revenues, with the conclusion that:

> Any procedure designed to bring about the complete electrification of Chicago's railroad terminals which is based upon the application of an arbitrary to the traffic of Chicago, will constitute a tax which must be borne, directly or indirectly, by the business interests of the city. The practicability of such a tax is a matter which has not been studied by the Committee.

Emphasis must be given to the fact that the Committee's conclusions as to financial practicability apply to the complete electrification of Chicago's railroad terminals. The financial practicability, under present-day conditions, of electrification as it might be applied to individual roads or to single services of individual roads, is a matter which has not been investigated by the Committee and concerning which no opinion is expressed.

PART VI

SUMMARY OF CONCLUSIONS WITH REFERENCE TO ATMOSPHERIC POLLUTION

601. RECOMMENDATIONS BASED UPON THE COMMITTEE'S STUDIES

SYNOPSIS: The researches of the Committee have developed many matters which are of interest to those who are concerned with Chicago's problem of reducing atmospheric pollution. It is the purpose of this chapter to set forth the more important of these in the form of recommendations.

601.01 Conclusions and Recommendations: The work of the Committee, in all its phases, has been an outgrowth of a desire on the part of the people of Chicago for a clearer and cleaner atmosphere. The essential facts, as revealed by the systematic researches of the Committee concerning the extent and character of the more important agencies affecting atmospheric purity, the methods to be employed and the difficulties to be met in any attempt to deal with them, have been duly set forth. There may now be presented, as a concluding summary of the report, such recommendations as are likely to prove serviceable to the city in its subsequent efforts to improve the purity of its atmosphere. These recommendations are based upon the conviction that pure air is essential to the health and comfort of an urban population and that it is the imperative duty of the authorities of the city of Chicago to secure, through persistent and intelligent action, a clean atmosphere. The Committee's recommendations are as follows:

1. That there be created by the city, a permanent Pure Air Commission, the membership of which shall be made up of persons possessing high technical qualifications.

2. That financial support be placed at the command of the Commission, which shall be sufficient adequately to provide for the organization and development of investigations of a highly scientific character.

3. That the Commission be empowered to investigate all sources of air pollution, to determine, by experiment or otherwise, the most effective means for mitigating or eliminating such pollution, and that, so far as practicable, it be invested with power to enforce obedience to its decisions.

4. That no materials shall be employed in paving without the consent of the Commission, to the end that dust creating pavements may be abolished.

5. That the paving and cleaning of alleys and other highways shall be subject to the supervision of the Commission.

6. That the Commission shall have power to require that the wrecking and erection of buildings shall proceed by methods which will protect the air from all unnecessary pollution.

7. That the Commission shall have the power to require roofs to be cleaned and other minor sources of air pollution to be abated.

8. That new installations of boiler and other furnaces be permitted only as licensed by the Commission, which shall have power, under reasonable rules, to determine the character of the installations.

9. That the Commission be charged with the duty of investigating present practice in the construction and operation of domestic furnaces, with a view to so perfecting such practice that fuels now used may be burned without objectionable air pollution, or to so changing the character of fuels as to accomplish the same result.

10. That the Commission be charged with the duty of investigating the construction and operation of metallurgical and high pressure steam boiler furnaces, with a view to eliminating, so far as practicable, the air pollution for which such furnaces are responsible, and that it formulate and enforce regulations under which such furnaces shall hereafter be constructed and operated.

11. That the Commission be charged with the duty of investigating the pollution of the air by railroad locomotives, by steamboats and by other transportation agencies making use of movable engines, of devising methods of abating air pollution from these sources and of enforcing such provisions for the suppression of air pollution as may be found necessary.

It is not the opinion of the Committee that radical action should be expected of the Pure Air Commission, or that action involving abandonment of the use of Illinois and Indiana coal is either advisable or practicable, or that action involving the general abandonment or rebuilding of existing boiler or heating plants, either stationary or portable, is advisable or practicable, or that the immediate or general electrification of railroads for the purpose of eliminating their part in air pollution is under present conditions advisable or practicable. It is deemed advisable, however, that all efforts to improve existing conditions shall be carried on with due regard to the responsibility of each of the fuel consuming services for its contribution to the pollution of the atmosphere, and that such changes as may be determined upon may be gradually made, with due regard to financial and mechanical difficulties.

The precise relations to be sustained by the proposed Pure Air Commission, to existing municipal administrative individuals or bodies, are assumed to be matters of detail, which have not been investigated by the Committee and concerning which no opinion is expressed.

END OF THE REPORT

APPENDIX

APPENDIX

TERRITORIAL GROWTH OF CHICAGO

701.01 Growth of Chicago by Annexations: The statistics of annexations to Chicago, from its incorporation as a town in 1835 down to 1911, are presented in table CDXXVII. In compiling the statistics of early annexations, contemporary newspaper estimates and estimates made by early residents of the city have been compared with other information available. The figures given are usually the mean of those obtained from two or more sources.

A graphic presentation of the growth of Chicago, by annexations, is shown by the map, fig. 687. The growth of Chicago in population and area, from 1860 to 1910, is shown by fig. 688. The changes in Chicago's territorial limits, by decades from 1860 to 1910 and for the year 1912, are shown by figs. 689 to 695, inclusive. The changes in municipal ward boundaries of Chicago, by decades from 1860 to 1910 and as created by ordinance in December, 1911, and January, 1912, are shown by figs. 696 to 702, inclusive.

CHANGES IN POPULATION OF ILLINOIS, OF COOK COUNTY AND OF THE CITY OF CHICAGO

701.02 Sources of Information: The principal factors involved in a study of the population of any American city are immigration, emigration, migration, annexation, birth rate and death rate. The facts herein presented are based upon the reports of the United States Census Bureau. These have been supplemented by the records of the Federal Bureau of Immigration and by the statements of the Trans-Atlantic Passenger Conference.

701.03 Migration of Native-Born Persons to and from Illinois: Statistics relating to the population of Illinois, born and living in that state, the migration of native-born persons to and from Illinois and the net gain or loss due to migration are presented in table CDXXVIII. The figures given in this and in many of the following tables are based upon the reports of the

TABLE CDXXVII. STATISTICS OF ANNEXATIONS TO CHICAGO

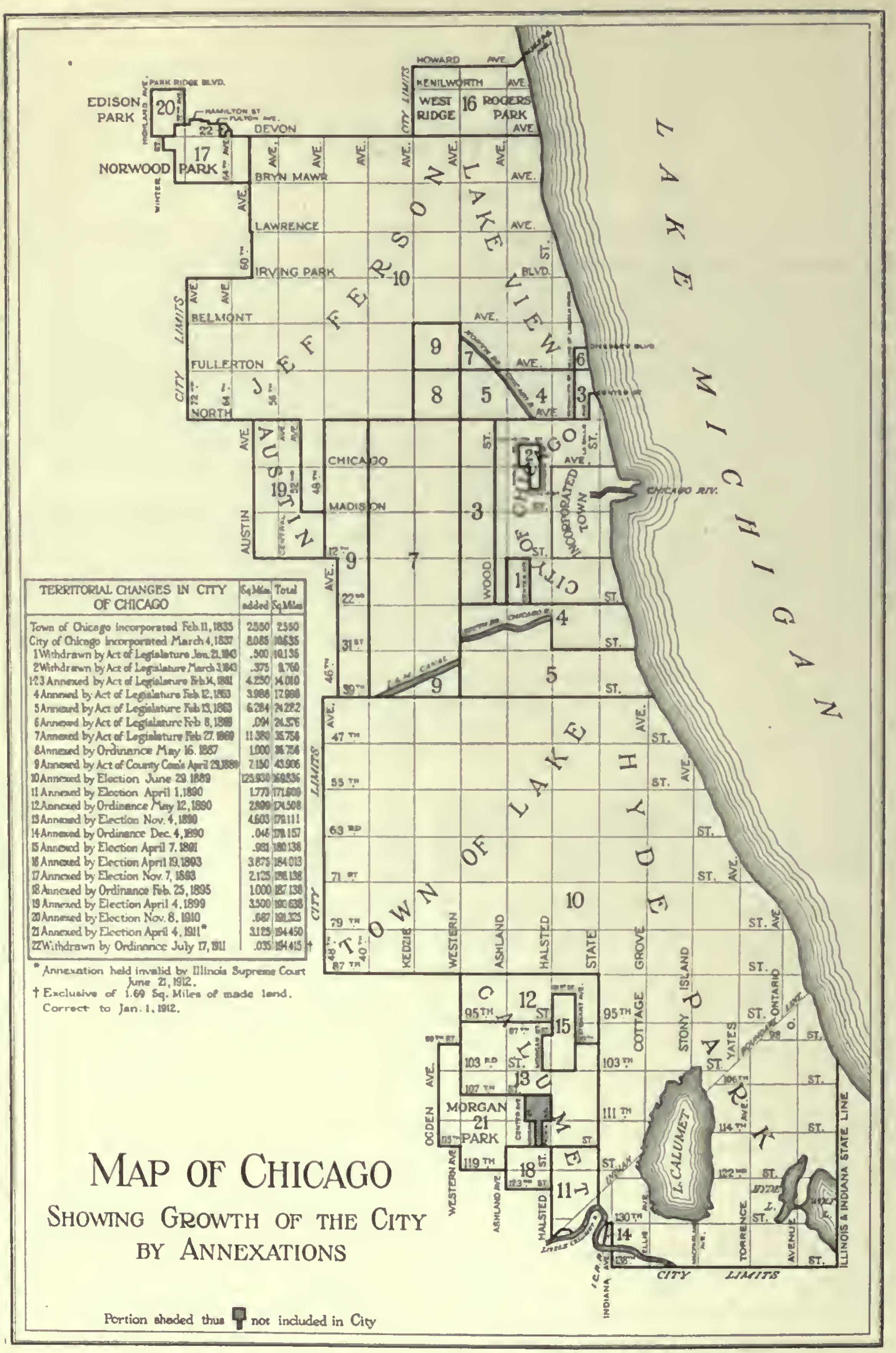
Name or Description of Annexed Territory	Method of Annexation	Date Annexed	Area Annexed Sq. Miles	Total Area of City	Population of Acquired Territory at Time of Annexation	Estimate of Population Based on
1	2	3	4	5	6	7
Town of Chicago	Incorporated	Feb. 11, 1835	2.550	2.550	3,279	Andreas' History of Chicago, Vol. 1.
City of Chicago	Incorporated	Mar. 4, 1837	8.085	10.635	4,066	School Census of July 1, 1837.
(See map, fig. 687, for location)	Act of State Legislature	Jan. 21, 1843	—.500*	10.135	5 †	See foot note.
(See map, fig. 687, for location)	Act of State Legislature	Mar. 3, 1843	—.375	9.760	7 †	See foot note.
(See map, fig. 687, for location)	Act of State Legislature	Feb. 14, 1851	4.250	14.010	75 †	See foot note.
(See map, fig. 687, for location)	Act of State Legislature	Feb. 12, 1853	3.988	17.998	800 †	See foot note.
(See map, fig. 687, for location)	Act of State Legislature	Feb. 13, 1863	6.284	24.282	6,480	See report of Supt. of Schools for 1863, p. 14.
North end of Lincoln Park	Act of State Legislature	Feb. 8, 1869	0.094	24.376	00 †	
(See map, fig. 687, for location)	Act of State Legislature	Feb. 27, 1869	11.380	35.756	1,925	Vote on Park Systems. See *Chicago Times*, March 24, 1869.
(See map, fig. 687, for location)	Ordinance of Chicago	May 16, 1887	1.000	36.756	12,400	Comparison of newspaper estimates and U. S. Census of 1890.
Brighton Park and Central Park districts of Cicero, Maplewood District of Jefferson	Act of Cook Co. Com'rs	Apr. 29, 1889	7.150	43.906	12,600	Reduced newspaper estimates. See *Chicago Tribune*, April 30, 1889.
Part of Cicero; city of Lake View; towns of Jefferson and Lake; village of Hyde Park	Election	June 29, 1889	125.930	169.836	210,700	Deduced from U. S. Census of 1890.
Village of Gano in southwest part of the present city	Election	Apr. 1, 1890	1.773	171.609	2,000	Newspaper estimate. See *Chicago Tribune* of April 1, 1890.
Unincorporated territory known as South Englewood in southwest part of the present city	Ordinance of Chicago	May 12, 1890	2.899	174.508	1,750	Comparison of newspaper estimates.
Village of Washington Heights; village of West Roseland	Election	Nov. 4, 1890	4.603	179.111	3,840	U. S. Census of 1890.
Lies between the Illinois Central R.R. and Indiana Avenue from 130th Street to the Calumet River	Ordinance of Chicago	Dec. 4, 1890	0.046	179.157	00 †	See foot note.
Village of Fernwood in southwest part of the present city	Election	Apr. 7, 1891	0.981	180.138	000	U. S. Census of 1890.
Villages of West Ridge and Rogers Park	Election	Apr. 19, 1893	3.875	184.013	2,400	Comparison of newspaper estimates and votes cast at the election.
Village of Norwood Park	Election	Nov. 7, 1893	2.125	186.138	1,000	Newspaper estimate. See *Chicago Tribune* of November 8, 1893.
Part of the town of Calumet; lies between Ashland Avenue and Halsted Street from 115th to 123d streets.	Ordinance of Chicago	Feb. 25, 1895	1.000	187.138	300	Number of signatures to petition for annexation.
Part of the town of Cicero east of Austin Avenue	Election	Apr. 4, 1899	3.500	190.638	11,215	U. S. Census of 1900.
Village of Edison Park	Election	Nov. 8, 1910	0.687	191.325	543	U. S. Census of 1910.
Village of Morgan Park ‡	Election	Apr. 4, 1911	3.125	194.450	3,830	U. S. Census of 1910.
Part of former village of Norwood Park	Ordinance of Chicago	July 17, 1911	0.035	194.415¶		Inspection of territory.

* Minus sign (—) denotes withdrawal of territory.

† Estimates of population based upon the recollection of early residents. No information could be obtained from old directories, histories or newspapers.

‡ Election held invalid by Supreme Court of Illinois, June 21, 1912. Re-annexed, 1914.

¶ Exclusive of 1.69 square miles of made land.



TERRITORIAL CHANGES IN CITY OF CHICAGO	Sq. Miles added	Total Sq. Miles
Town of Chicago incorporated Feb. 11, 1835	2.550	2.550
City of Chicago incorporated March 4, 1837	8.085	10.635
1 Withdrawn by Act of Legislature Jan. 21, 1843	.500	10.135
2 Withdrawn by Act of Legislature March 3, 1843	.375	9.760
1-2-3 Annexed by Act of Legislature Feb. 14, 1851	4.250	14.010
4 Annexed by Act of Legislature Feb. 12, 1853	3.988	17.998
5 Annexed by Act of Legislature Feb. 13, 1863	6.284	24.282
6 Annexed by Act of Legislature Feb. 8, 1869	.094	24.376
7 Annexed by Act of Legislature Feb. 27, 1869	11.380	35.756
8 Annexed by Ordinance May 16, 1887	1.000	36.756
9 Annexed by Act of County Com's April 29, 1889	7.150	43.906
10 Annexed by Election June 29, 1889	125.930	169.836
11 Annexed by Election April 1, 1890	1.773	171.609
12 Annexed by Ordinance May 12, 1890	2.899	174.508
13 Annexed by Election Nov. 4, 1890	4.603	179.111
14 Annexed by Ordinance Dec. 4, 1890	.046	179.157
15 Annexed by Election April 7, 1891	.981	180.138
16 Annexed by Election April 19, 1893	3.875	184.013
17 Annexed by Election Nov. 7, 1893	2.125	186.138
18 Annexed by Ordinance Feb. 25, 1895	1.000	187.138
19 Annexed by Election April 4, 1899	3.500	190.638
20 Annexed by Election Nov. 8, 1910	.687	191.325
21 Annexed by Election April 4, 1911*	3.125	194.450
22 Withdrawn by Ordinance July 17, 1911	.035	194.415†

* Annexation held invalid by Illinois Supreme Court June 21, 1912.

† Exclusive of 1.69 Sq. Miles of made land.

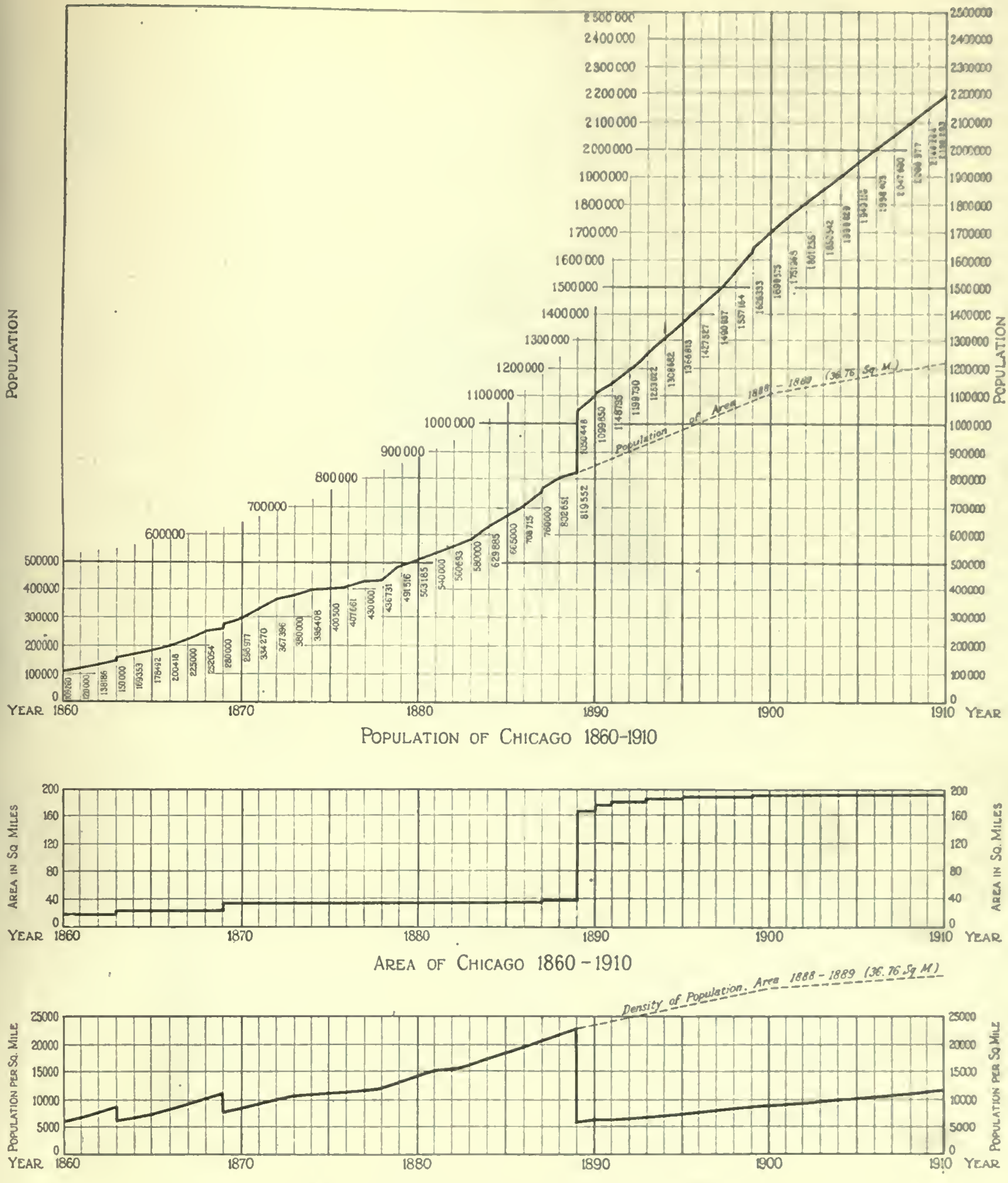
Correct to Jan. 1, 1912.

MAP OF CHICAGO

SHOWING GROWTH OF THE CITY BY ANNEXATIONS

Portion shaded thus ▮ not included in City

FIG. 687. TERRITORIAL GROWTH OF CHICAGO BY ANNEXATIONS



Population of Chicago 1860-1910

Area of Chicago 1860 - 1910

Population per Square Mile of Chicago 1860-1910

FIG. 688. CHANGES IN POPULATION AND AREA OF CHICAGO, BASED UPON UNITED STATES CENSUS AND MUNICIPAL REPORTS

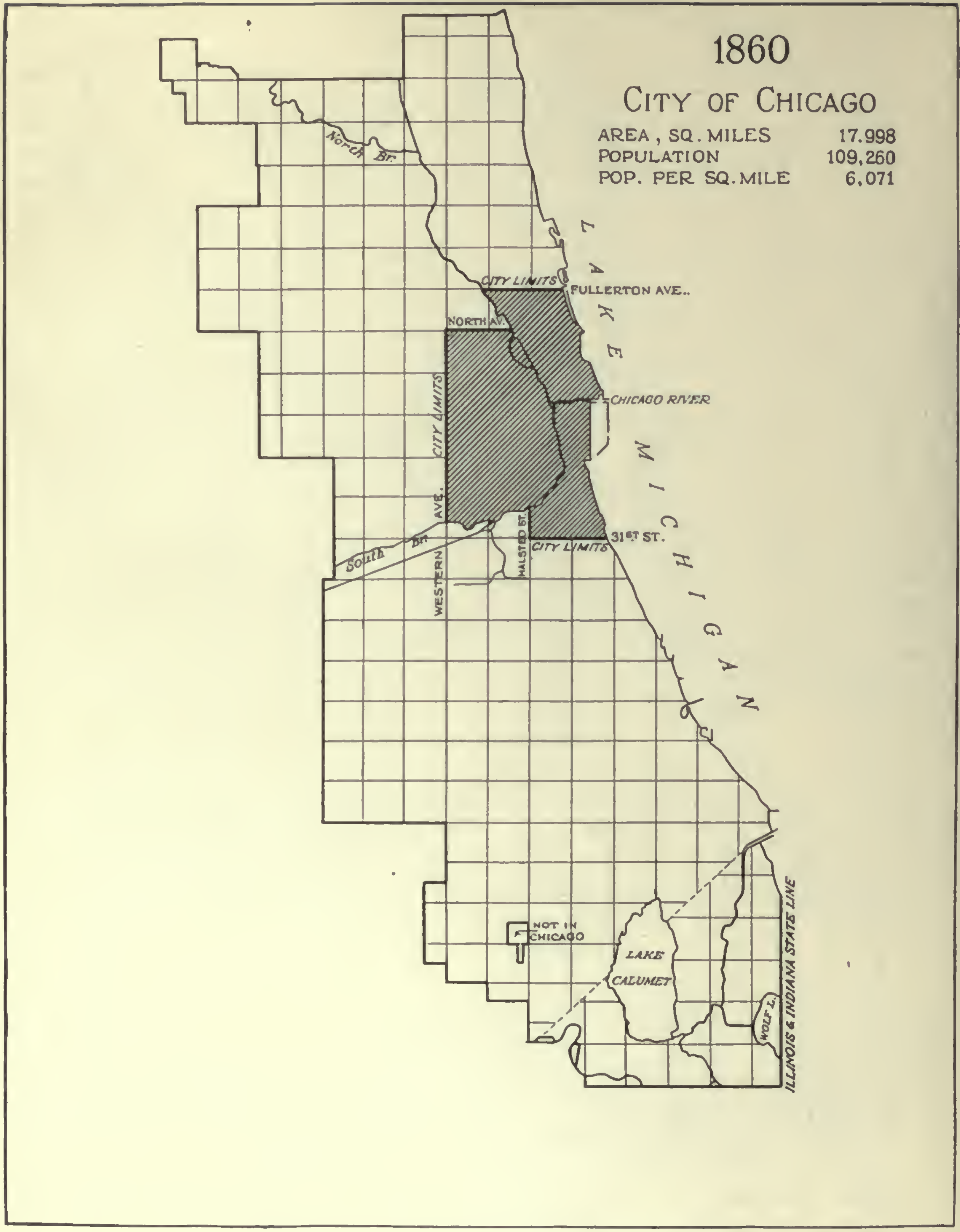


FIG. 689. CHICAGO'S TERRITORIAL LIMITS IN 1860

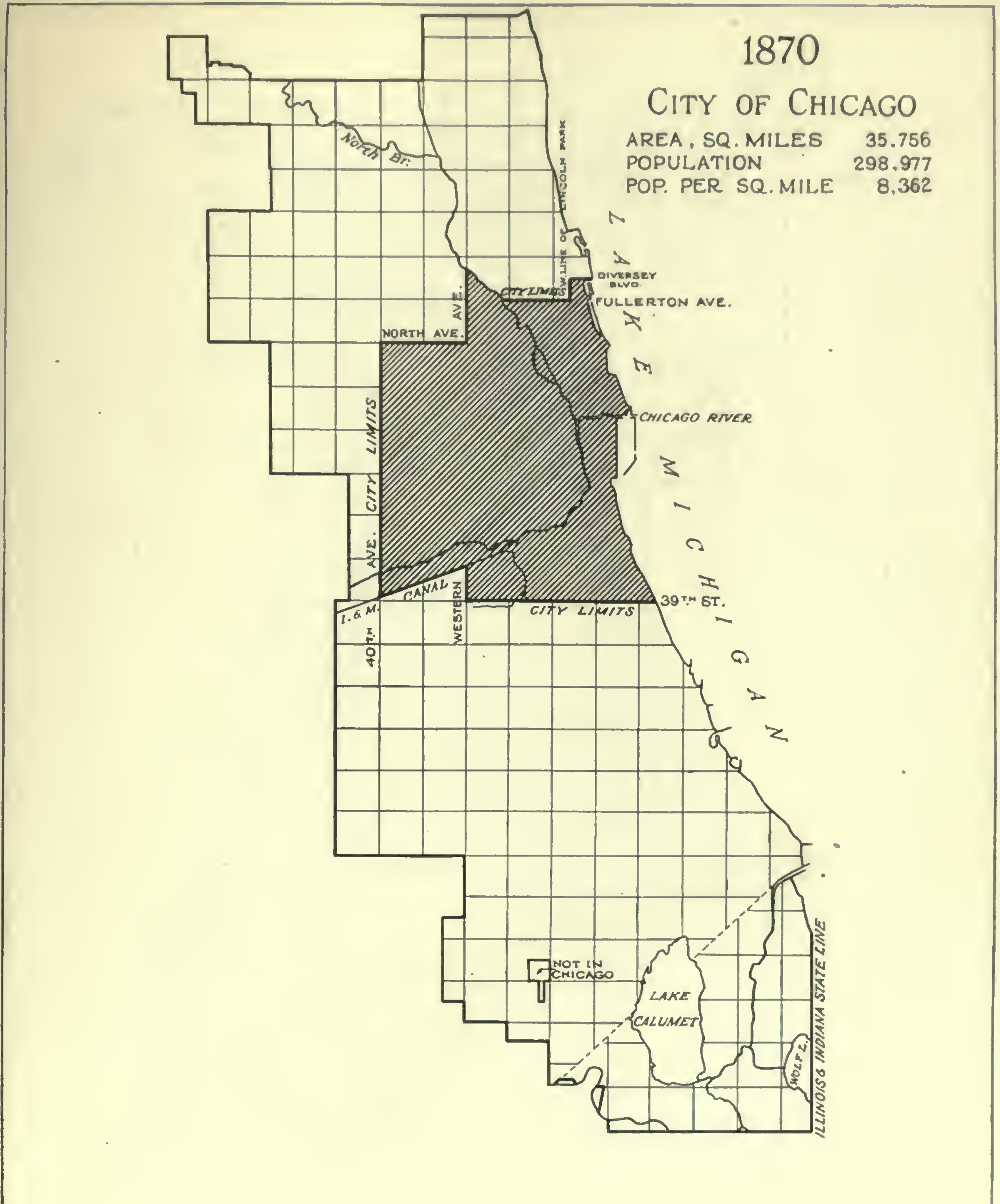


FIG. 690. CHICAGO'S TERRITORIAL LIMITS IN 1870

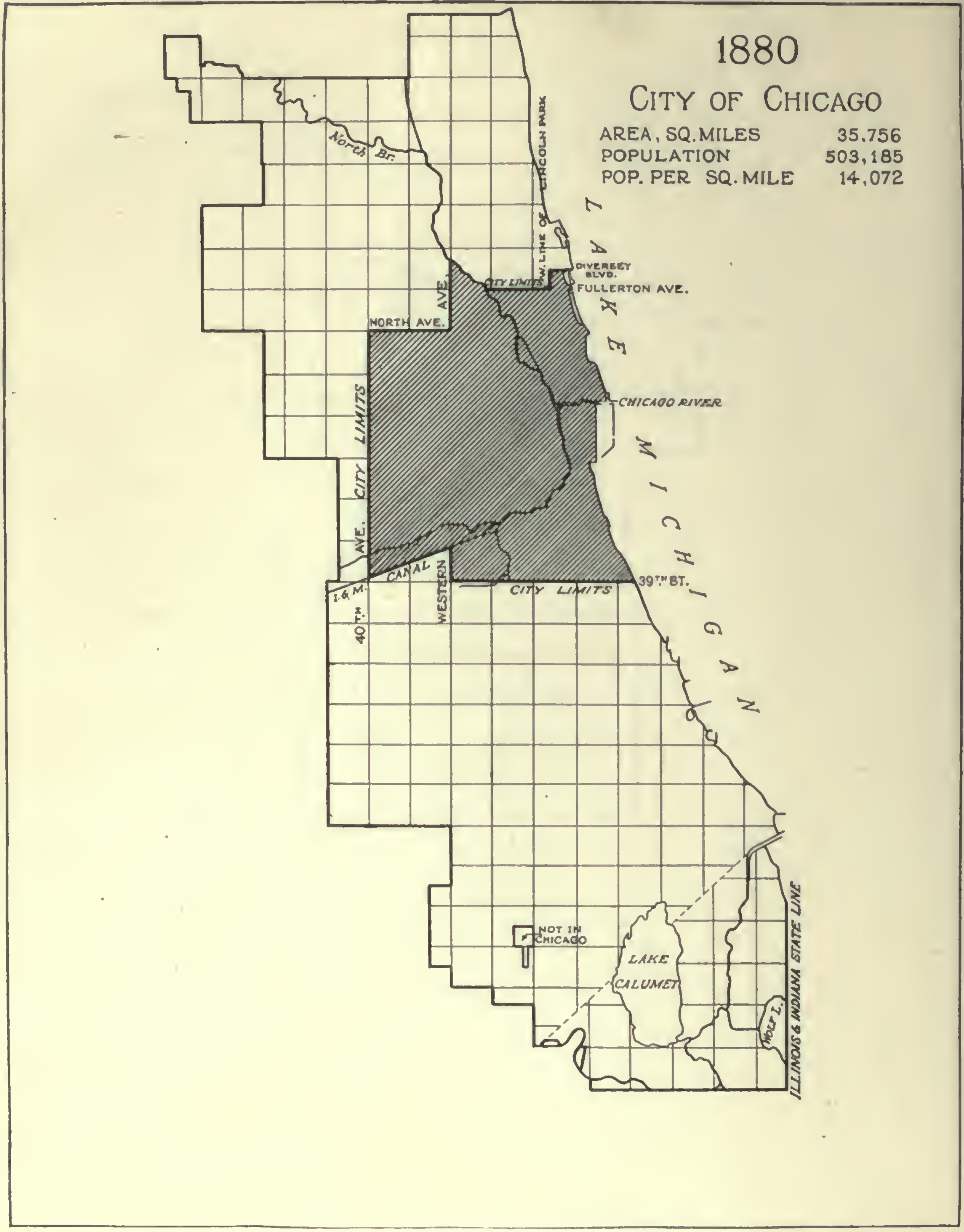


FIG. 691. CHICAGO'S TERRITORIAL LIMITS IN 1880

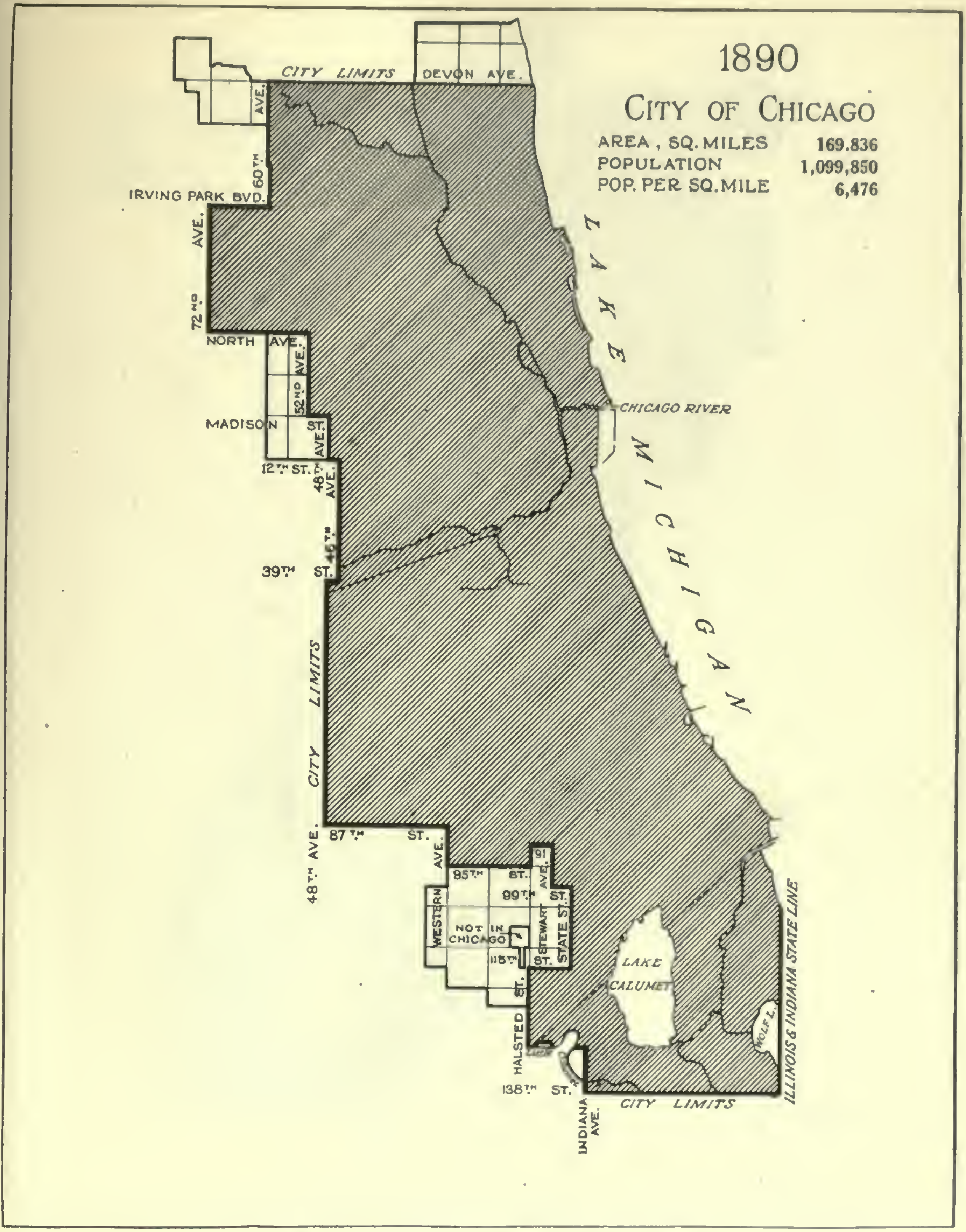


FIG. 692. CHICAGO'S TERRITORIAL LIMITS IN 1890

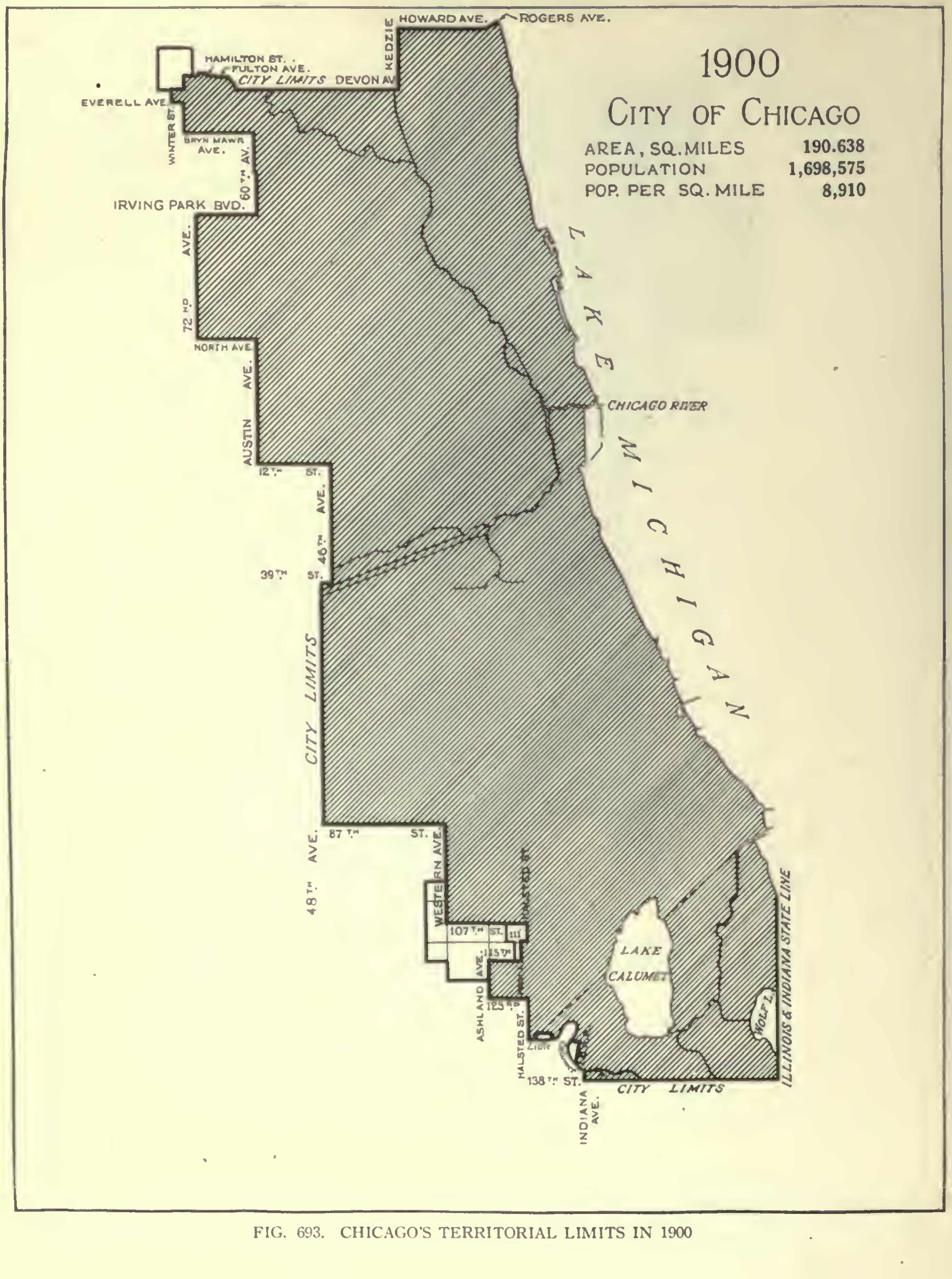


FIG. 693. CHICAGO'S TERRITORIAL LIMITS IN 1900

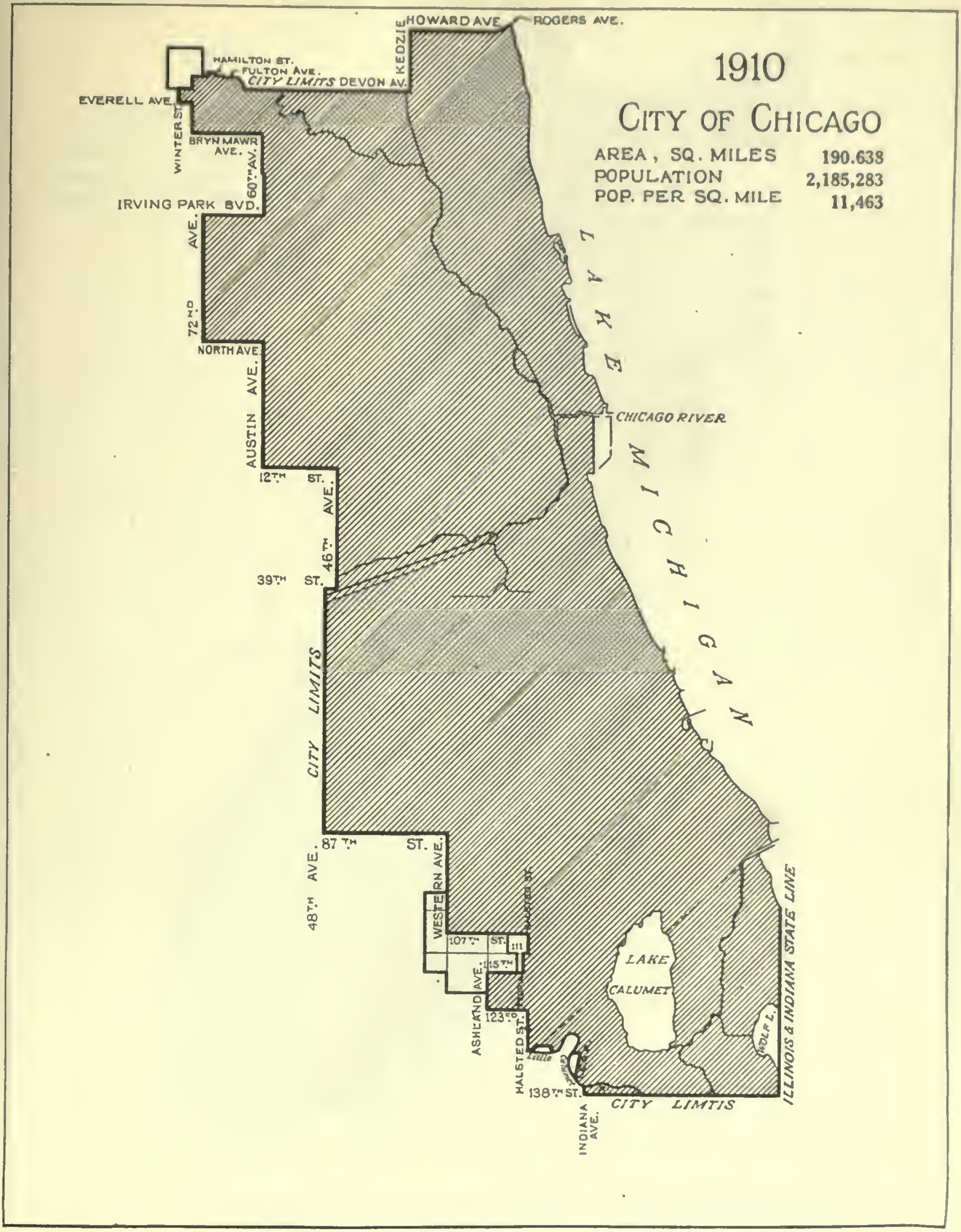


FIG. 694. CHICAGO'S TERRITORIAL LIMITS IN 1910

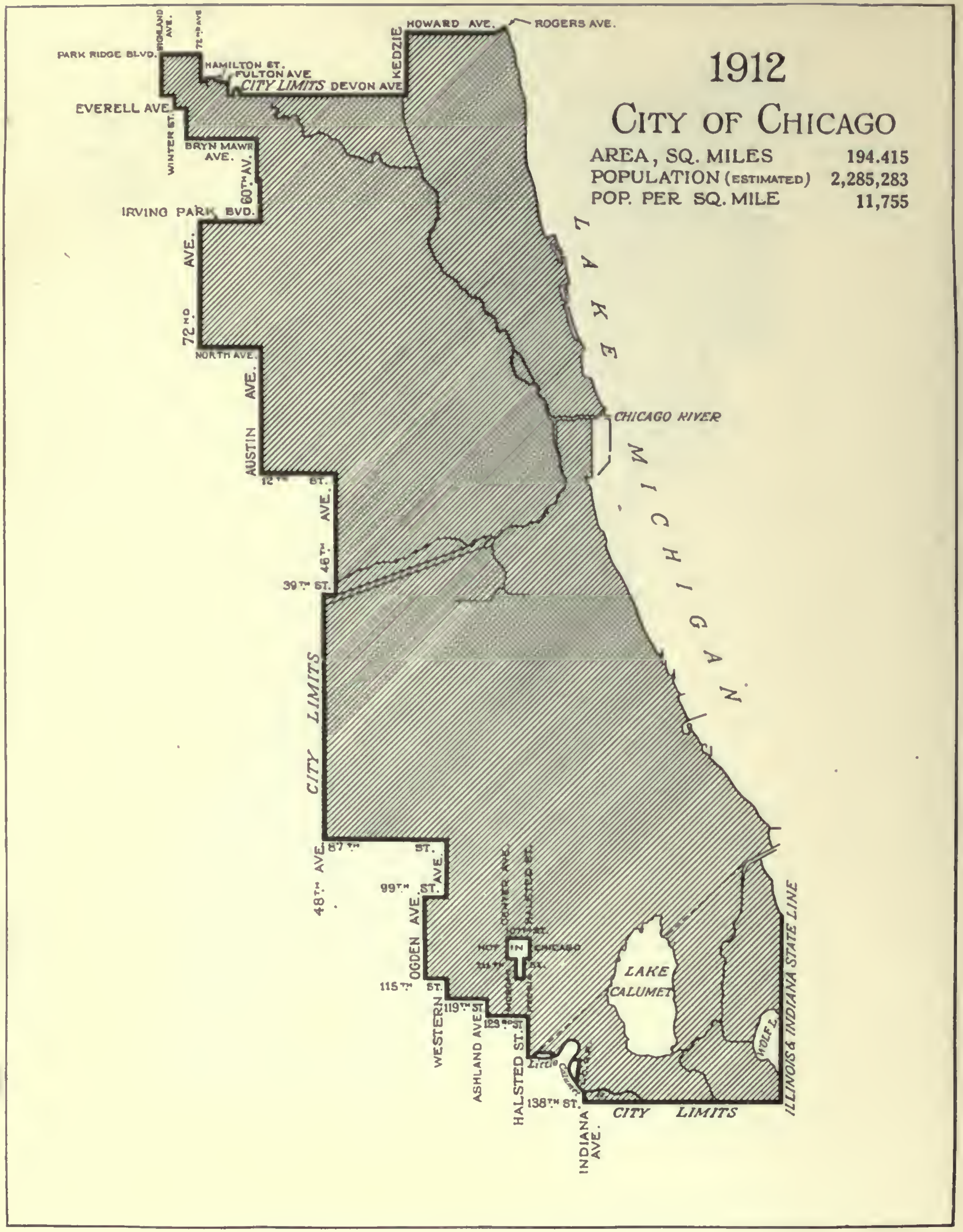
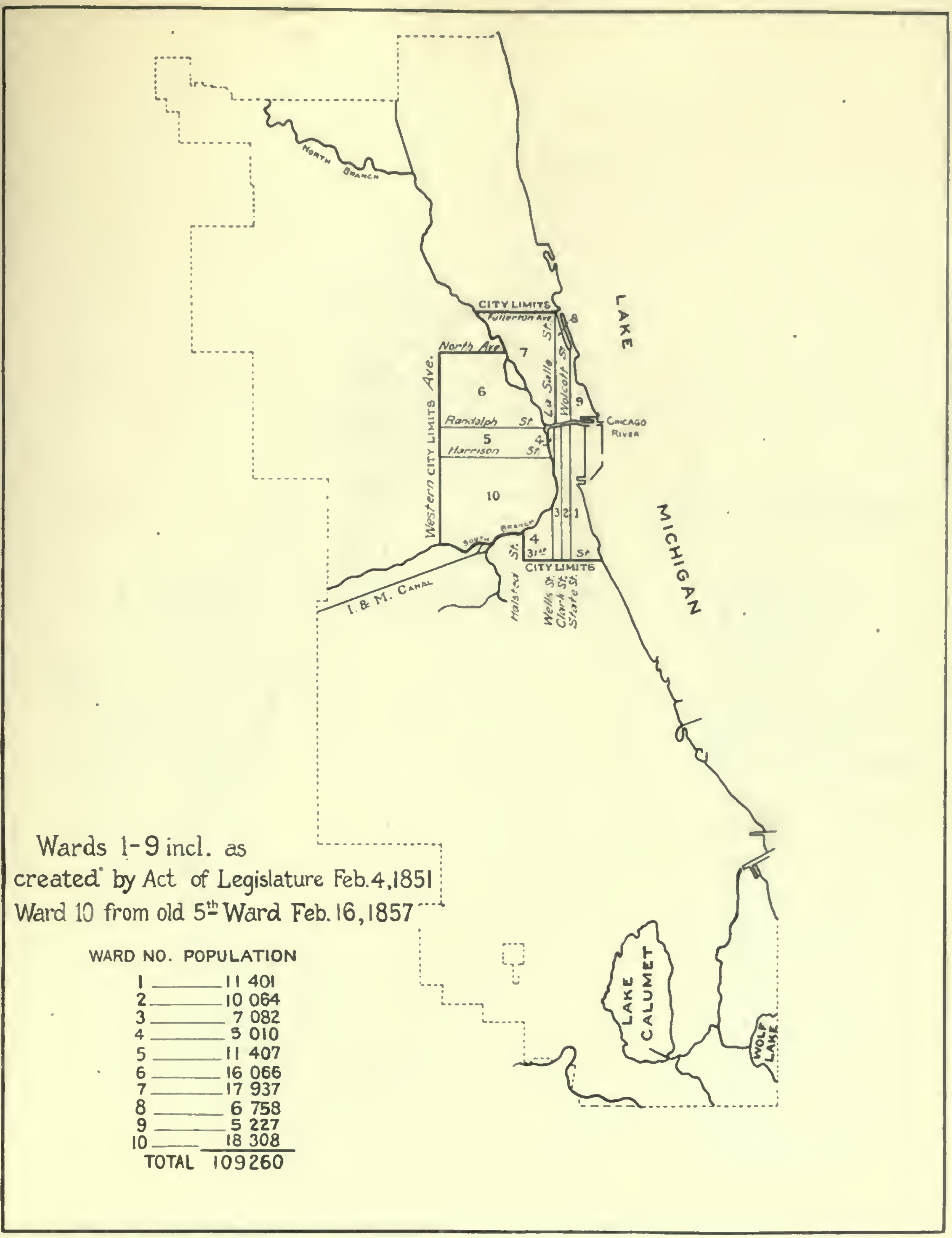


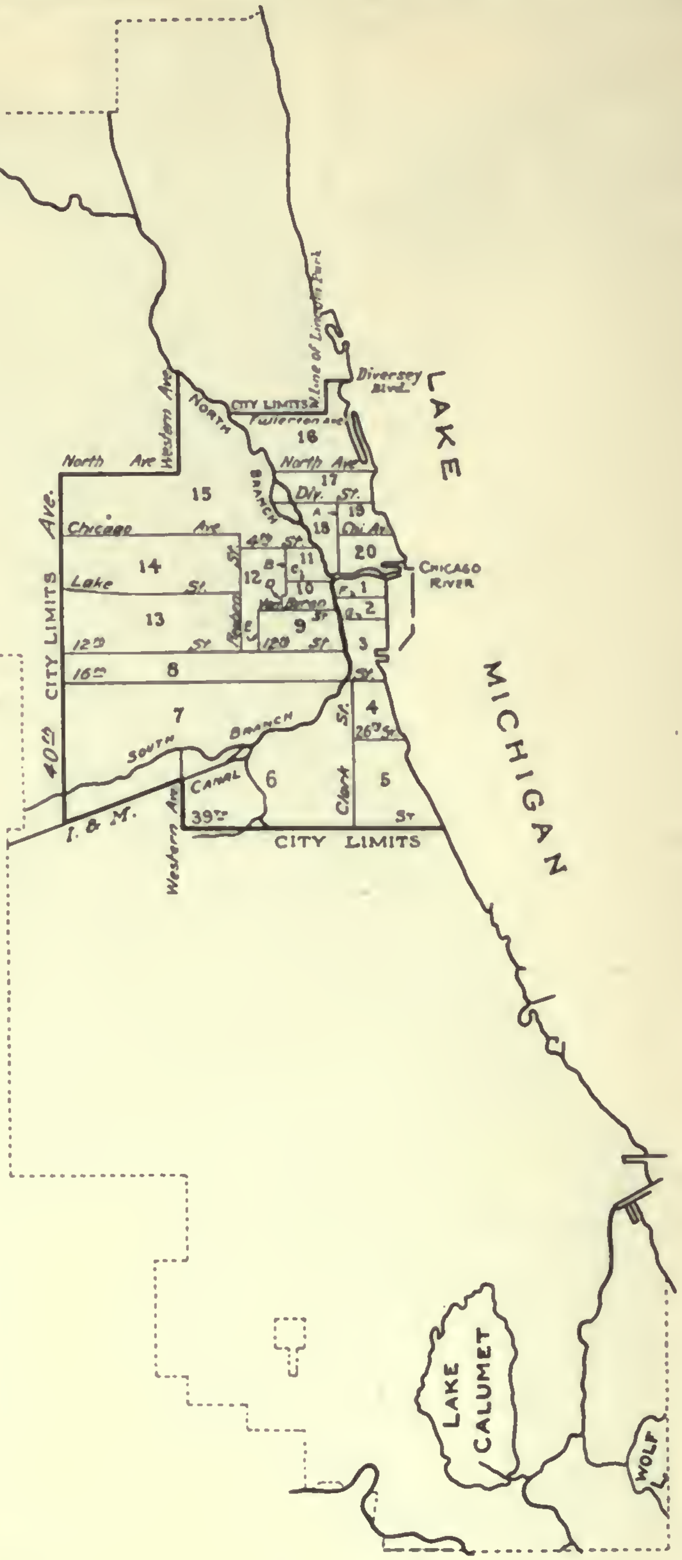
FIG. 695. CHICAGO'S TERRITORIAL LIMITS IN 1912



Wards 1-9 incl. as
created by Act of Legislature Feb. 4, 1851
Ward 10 from old 5th Ward Feb. 16, 1857

WARD NO.	POPULATION
1	11 401
2	10 064
3	7 082
4	5 010
5	11 407
6	16 066
7	17 937
8	6 758
9	5 227
10	18 308
TOTAL	109260

FIG. 696. WARD BOUNDARIES OF CHICAGO AS USED IN UNITED STATES CENSUS OF 1860



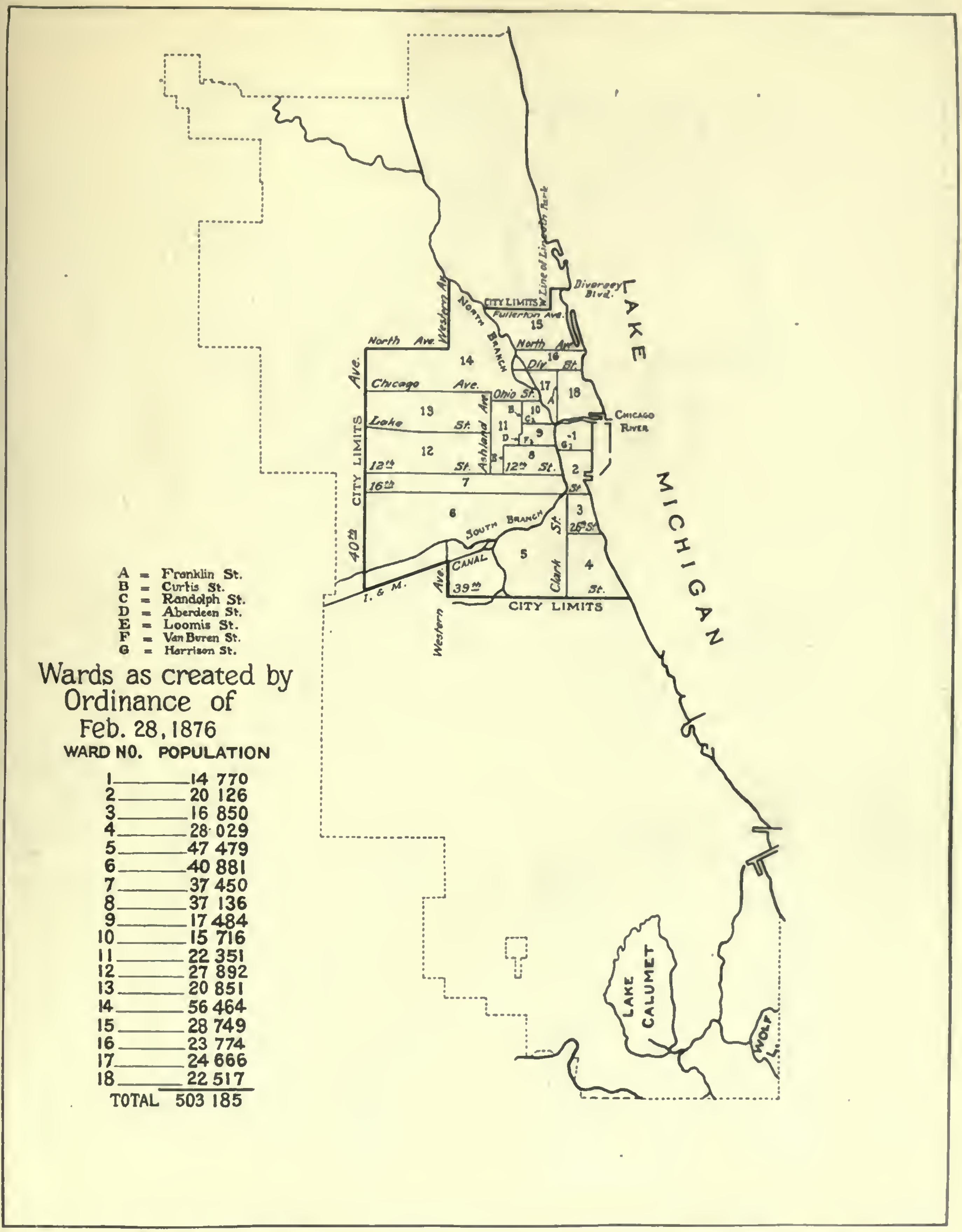
NOTE: Reuben St. = Ashland Ave.
4th St. = Ohio St.

A = Franklin St.
B = Curtis St.
C = Randolph St.
D = Aberdeen St.
E = Loomis St.
F = Monroe St.
G = Harrison St.

Wards as created by Act of Legislature March 10, 1869

WARD NO.	POPULATION
1	6 522
2	14 320
3	17 681
4	12 174
5	11 566
6	19 445
7	13 854
8	22 911
9	27 817
10	13 771
11	15 065
12	13 976
13	8 928
14	9 035
15	20 361
16	14 045
17	18 078
18	17 084
19	8 716
20	13 628
TOTAL	298.977

FIG. 697. WARD BOUNDARIES OF CHICAGO AS USED IN UNITED STATES CENSUS OF 1870

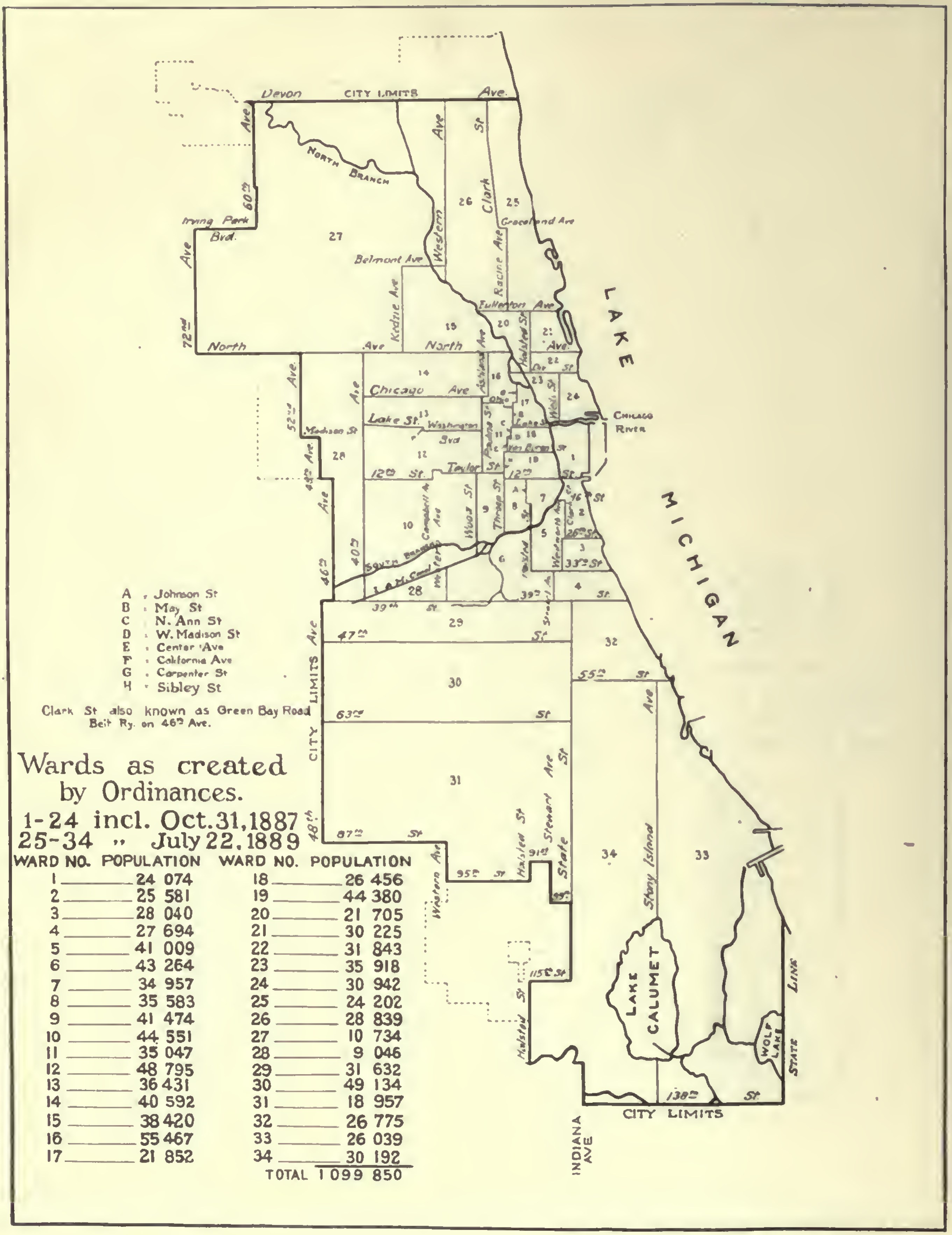


A = Franklin St.
B = Curtis St.
C = Randolph St.
D = Aberdeen St.
E = Loomis St.
F = Van Buren St.
G = Harrison St.

Wards as created by Ordinance of Feb. 28, 1876

WARD NO.	POPULATION
1	14 770
2	20 126
3	16 850
4	28 029
5	47 479
6	40 881
7	37 450
8	37 136
9	17 484
10	15 716
11	22 351
12	27 892
13	20 851
14	56 464
15	28 749
16	23 774
17	24 666
18	22 517
TOTAL	503 185

FIG. 698. WARD BOUNDARIES OF CHICAGO AS USED IN UNITED STATES CENSUS OF 1880



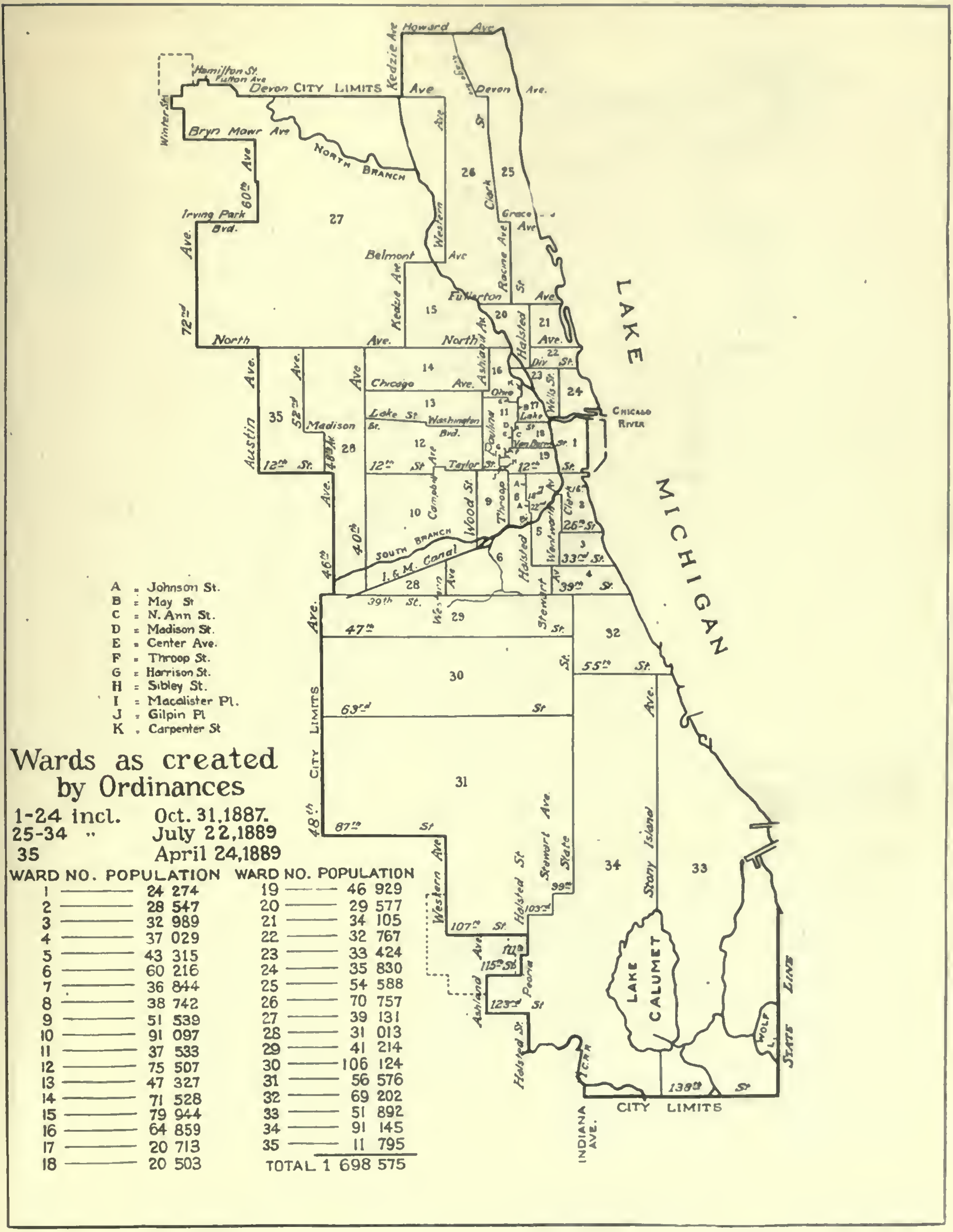
A = Johnson St
B = May St
C = N. Ann St
D = W. Madison St
E = Center Ave
F = California Ave
G = Carpenter St
H = Sibley St

Clark St also known as Green Bay Road
Belt Ry. on 46th Ave.

Wards as created
by Ordinances.
1-24 incl. Oct. 31, 1887
25-34 " July 22, 1889

WARD NO.	POPULATION	WARD NO.	POPULATION
1	24 074	18	26 456
2	25 581	19	44 380
3	28 040	20	21 705
4	27 694	21	30 225
5	41 009	22	31 843
6	43 264	23	35 918
7	34 957	24	30 942
8	35 583	25	24 202
9	41 474	26	28 839
10	44 551	27	10 734
11	35 047	28	9 046
12	48 795	29	31 632
13	36 431	30	49 134
14	40 592	31	18 957
15	38 420	32	26 775
16	55 467	33	26 039
17	21 852	34	30 192
		TOTAL	1 099 850

FIG. 699. WARD BOUNDARIES OF CHICAGO AS USED IN UNITED STATES CENSUS OF 1890



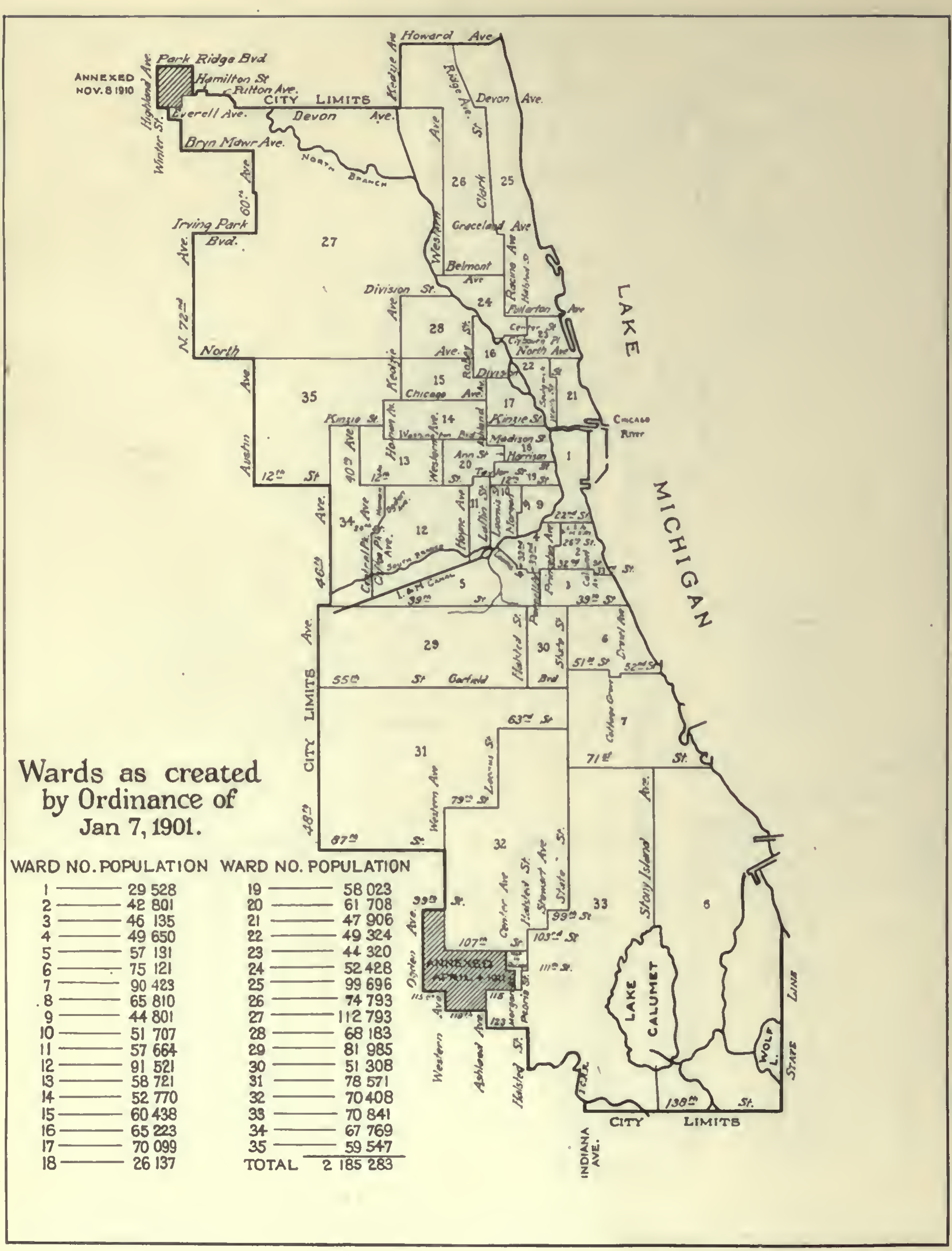
A = Johnson St.
B = May St
C = N. Ann St.
D = Madison St.
E = Center Ave.
F = Throop St.
G = Harrison St.
H = Sibley St.
I = Macalister Pl.
J = Gilpin Pl
K = Carpenter St

Wards as created by Ordinances

1-24 incl. Oct. 31, 1887.
25-34 " July 22, 1889
35 April 24, 1889

WARD NO.	POPULATION	WARD NO.	POPULATION
1	24 274	19	46 929
2	28 547	20	29 577
3	32 989	21	34 105
4	37 029	22	32 767
5	43 315	23	33 424
6	60 216	24	35 830
7	36 844	25	54 588
8	38 742	26	70 757
9	51 539	27	39 131
10	91 097	28	31 013
11	37 533	29	41 214
12	75 507	30	106 124
13	47 327	31	56 576
14	71 528	32	69 202
15	79 944	33	51 892
16	64 859	34	91 145
17	20 713	35	11 795
18	20 503	TOTAL	1 698 575

FIG. 700. WARD BOUNDARIES OF CHICAGO AS USED IN UNITED STATES CENSUS OF 1900



Wards as created by Ordinance of Jan 7, 1901.

WARD NO.	POPULATION	WARD NO.	POPULATION
1	29 528	19	58 023
2	42 801	20	61 708
3	46 135	21	47 906
4	49 650	22	49 324
5	57 131	23	44 320
6	75 121	24	52 428
7	90 423	25	99 696
8	65 810	26	74 793
9	44 801	27	112 793
10	51 707	28	68 183
11	57 664	29	81 985
12	91 521	30	51 308
13	58 721	31	78 571
14	52 770	32	70 408
15	60 438	33	70 841
16	65 223	34	67 769
17	70 099	35	59 547
18	26 137	TOTAL	2 185 283

FIG. 701. WARD BOUNDARIES OF CHICAGO AS USED IN UNITED STATES CENSUS OF 1910

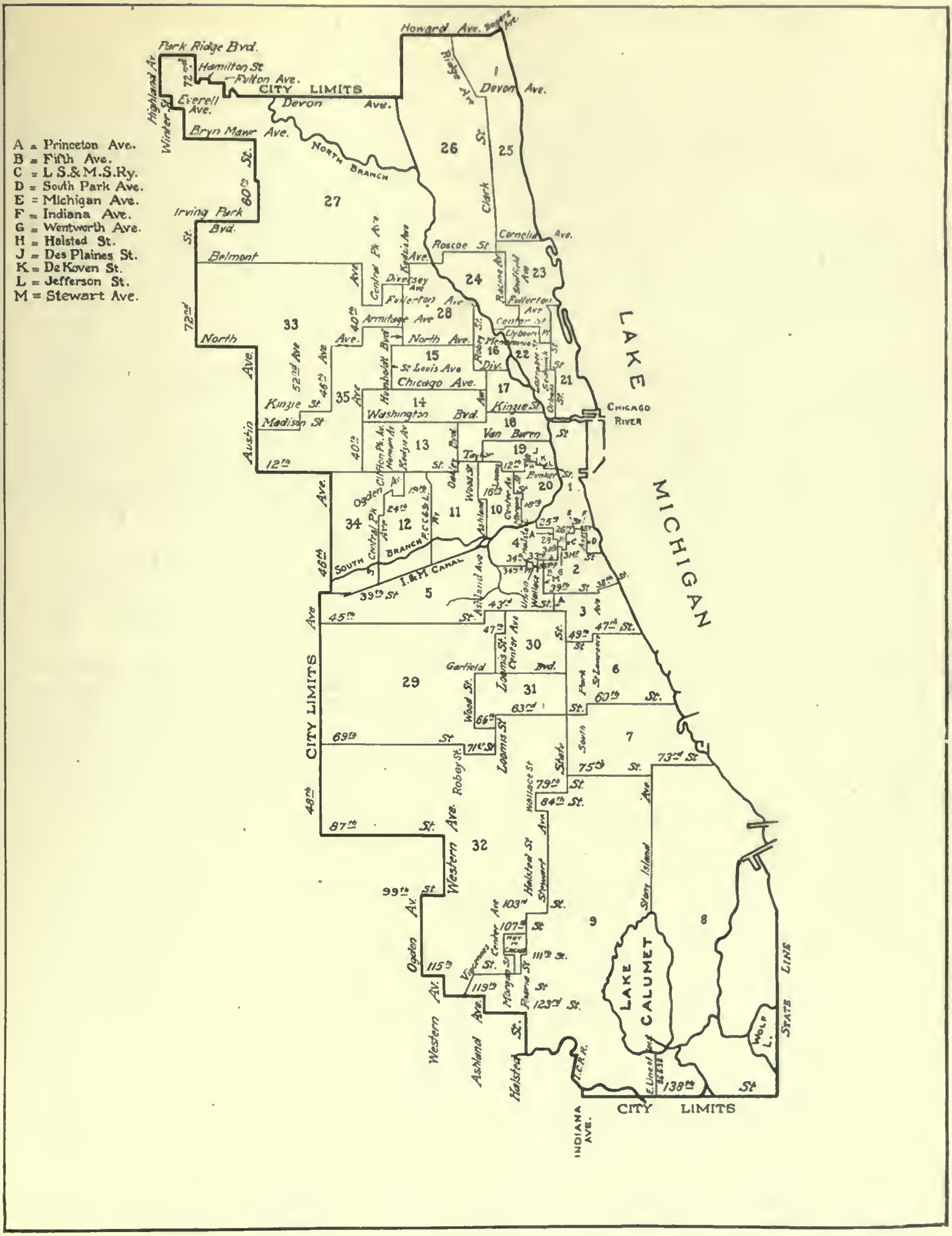


FIG. 702. WARD BOUNDARIES OF CHICAGO AS CREATED BY ORDINANCE OF DEC. 4, 1911, AND AMENDMENT OF JAN. 22, 1912

TABLE CDXXVIII. CHANGES IN POPULATION OF ILLINOIS AND MIGRATION OF NATIVE-BORN PERSONS TO AND FROM ILLINOIS, 1850-1910

Persons Born in Illinois						Persons Living in Illinois							
Year	Total Number	Living in Illinois		Living in Other States		Total Number	Born in Illinois		Born in Other States		Foreign-Born		Net Gain or Loss Due to Migration
		Number	Per Cent of Total Number Born in Illinois	Number	Per Cent of Total Number Born in Illinois		Number	Per Cent of Total Number Living in Illinois	Number	Per Cent of Total Number Living in Illinois	Number	Per Cent of Total Number Living in Illinois	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1850	389,507	343,618	88.22	45,880	11.78	851,470	343,618	40.36	393,313	46.19	114,539	13.45	347,424
1860	841,661	706,925	83.99	134,736	16.01	1,711,951	706,925	41.30	680,383	39.74	324,643	18.96	545,647
1870	1,479,410	1,189,503	80.40	289,907	19.60	2,539,891	1,189,503	46.83	835,190	32.88	515,198	20.29	545,283
1880	2,263,409	1,709,520	75.53	553,889	24.47	3,077,871	1,709,520	55.54	784,775	25.50	583,576	18.96	230,886
1890	3,014,005	2,196,288	72.87	817,717	27.13	3,826,351	2,196,288	57.40	787,716	20.59	842,347	22.01	—30,001*
1900	3,906,494	2,893,857	74.08	1,012,637	25.92	4,804,508	2,893,857	60.23	943,904	19.65	966,747	20.12	—68,733
1910	4,714,723	3,406,638	72.26	1,308,085	27.74	5,609,141	3,406,638	60.73	997,189	17.78	1,205,314	21.49	—310,896

* Minus sign (—) denotes decrease.

United States Census Bureau for the decades 1850 to 1910, inclusive.

The percentage of increase by decades in the population of Illinois, born and living in that state, and the migration of native-born persons to and from Illinois, from 1850 to 1910, are shown by table CDXXIX.

TABLE CDXXIX. PERCENTAGE OF INCREASE IN POPULATION OF ILLINOIS AND MIGRATION OF NATIVE-BORN PERSONS TO AND FROM ILLINOIS, 1850-1910

Decade	Persons Born in Illinois			Persons Living in Illinois		
	Total Number	Living in Illinois	Living in Other States	Total Number	Born in Other States	Foreign-Born
1	2	3	4	5	6	7
1850-1860	116.08	105.73	103.61	101.06	72.99	183.43
1860-1870	75.77	68.26	115.17	48.36	22.75	58.70
1870-1880	52.99	43.72	91.06	21.18	—6.04*	13.27
1880-1890	33.16	28.47	47.63	24.32	0.37	44.34
1890-1900	29.61	31.76	23.84	25.56	19.83	14.77
1900-1910	20.69	17.72	29.18	16.75	5.65	24.68
Average decennial increase..	51.50	46.50	74.70	36.91	16.78	48.03
Ratio (to 1) increase of whole period....	21.10	9.91	28.51	6.59	2.53	10.52

* Minus sign (—) denotes decrease.

A marked change has taken place in the effect, on the population of Illinois, of migration of native-born persons. In 1850, the number of persons born in Illinois and living in other states was 347,424 less than the number born in other states who were living in Illinois. In 1910 the number born in Illinois and living in other states exceeded by 310,896 the number born in other states who were living in Illinois. This change in the migration balance from gain to loss is the significant feature of the migration statistics for the entire period from 1850 to 1910.

The effect of this change in migration is modified by the fact that the population of the whole state in 1910 was nearly seven times as great as in 1850. In 1850, the influx of 347,424 persons represented nearly 41 per cent of the total population living in the state at that date; while in 1910 the efflux or loss due to migration, 310,896 persons, was little more than 5.5 per cent of the total population of the state. This change is significant in that its effect reverses conditions of an earlier period. It shows a tendency during the last three decades on the part of persons born in Illinois to move away from the state to an extent that has not been offset by the tendency of native-born persons to move into Illinois.

Another phase of the same tendency is to be noted in the fact that the number of persons born and living in Illinois forms a decreasing proportion of the total number born in that state; for in 1850, the number born and living in Illinois represented 88.22 per cent of the number born in the state, while in 1910, the ratio was only 72.26 per cent.

Although the proportion to the total population of those born and living in Illinois increased from 40.36 per cent in 1850 to 60.73 per cent in 1910, the proportion of those born in other states and living in Illinois decreased in the same period from 46.19 per cent of the total to 17.78 per cent.

701.04 Comparative Increase in Population Born in Other States and Living in Chicago and in Illinois Exclusive of Chicago: Table CDXXX presents statistical facts relating to persons born in other states and living in Chicago and in Illinois outside of Chicago.

The first division of table CDXXX relates to the increases for Illinois as a whole, which have already been discussed. For the period from 1850 to 1910, the increases are in descending order, ranging from 72.99 per cent in the earliest decade to 5.65 per cent in the latest.

The increases in the number of native-born persons of other states living in Chicago are shown in the second division. For successive decades the percentages of increase due to this cause varied from 237.61 in 1860 to 12.52 in 1910. In terms of the increase of the first decade, the ratios of increase for the following periods are successively 2.14, 1.83, 6.00, 6.90 and 2.29. In the past 60 years, there has been a total increase of 376,498 in the population of Chicago due to migration from states other than Illinois.

From 1850 to 1860, the state of Illinois outside of Chicago gained, through migration of native-born persons of other states, 69.63 per cent over the number of this class in 1850. But on account of the shifting of this population, with losses from 1870 to 1890, the total increase from 1850 to 1910 was less than the increase from 1850 to 1860.

The relative attraction of the native-born population of other states to the city of Chicago and to the state of Illinois, exclusive of Chicago, will be noted by the changes in the proportion received by each. In the decade 1850 to 1860, 6.51 per cent of such native-born population of other states were living in Chicago, while 93.49 per cent were located in Illinois outside of the city. The city continued to receive an increasing proportion of the native-born persons migrating from other states and, in the period from 1900 to 1910, Chicago claimed 80.28 per cent, while 19.72 per cent went to the remainder of the state.

701.05 Increase and Decrease in the Population of Illinois Due to the Migration of Native-Born Persons: The number of native-born persons who migrated to or from Illinois during each decade from 1850 to 1910 is given in table CDXXXI, together with the net increases or decreases and the net gain or loss through migration as shown by the reports of the last six census years.

From 1850 to 1860, the migration from Illinois was 193.61 per cent of the number who, born in Illinois, were in 1850 living in other states. Though increasing numerically thereafter, the number of persons born in Illinois and migrating to other states forms a decreasing proportion of the number of such persons living in other states. The number who migrated to Illinois is combined with the number who migrated from that state, thus showing the net increase or decrease in population due to these movements for each decade. In the first of these decades, the movement to the state exceeded that from it, while in the following ten years, 1860 to 1870, there was a slight loss.

701.06 Population of Chicago, Classified by Place of Birth: The population of Chicago, classified according to place of birth, is shown by census years in table CDXXXII.

Table CDXXXII groups the population of Chicago for the last seven census years into three main classes. Two of these classes are the native-born persons of Illinois and the native-born persons of other states, while the third comprises those of foreign birth.

The growth in the total population of Chicago has been remarkable. The rate of this increase is shown by tables CDXXXIII to CDXXXVI, inclusive.

In summarizing the statistics of the population of Chicago, it appears that the changes in the proportion of each of the three classes during the past 60 years have been marked, and these changes are significant when considered in relation to the city's future population.

The most important change appears in the decreasing proportion of the foreign-born population. In 1850 the number of foreign-born amounted to 53.39 per cent of

TABLE CDXXX. COMPARATIVE INCREASE IN POPULATION BORN IN OTHER STATES AND LIVING IN CHICAGO AND IN ILLINOIS EXCLUSIVE OF CHICAGO, 1850-1910

Decade	Total Increase for Illinois	Per Cent of Increase	Living in Chicago			Living in Illinois Outside of Chicago		
			Total Increase	Per Cent of Increase over Preceding Decade	Per Cent of Total Increase for Illinois	Total Increase	Per Cent of Increase over Preceding Decade	Per Cent of Total Increase for Illinois
1	2	3	4	5	6	7	8	9
1850–1860	287,070	72.99	18,681	237.61	6.51	268,389	69.63	93.49
1860–1870	154,807	22.75	39,886	150.27	25.76	114,921	17.58	74.24
1870–1880	—50,415*	—6.036	34,169	51.44	67.78	—84,584	—11.00	—167.78
1880–1890	2,941	.375	112,156	111.49	3813.53	—109,215	—15.96	—3713.53
1890–1900	156,188	19.83	128,827	60.55	82.48	27,361	4.76	17.52
1900–1910	53,285	5.65	42,779	12.52	80.28	10,506	1.74	19.72
Totals	603,876	153.54	376,498	....	....	227,378	....	....

* Minus sign (—) denotes decrease.

TABLE CDXXXI. INCREASE AND DECREASE IN POPULATION OF ILLINOIS DUE TO MIGRATION OF NATIVE-BORN PERSONS 1850-1910

Decade	To Illinois		From Illinois		Net Increase or Decrease	Net Gain or Loss to Date through Migration
	Total Number	Per Cent of Increase	Total Number	Per Cent of Increase		
1	2	3	4	5	6	7
1850–1860	287,070	72.99	88,847	193.61	198,223	545,647 in 1860
1860–1870	154,807	22.75	155,171	115.17	—364	545,283 in 1870
1870–1880	—50,415*	—6.036	263,982	91.06	—314,397	230,886 in 1880
1880–1890	2,941	.375	263,828	47.63	—260,887	—30,001 in 1890
1890–1900	156,188	19.83	194,920	23.84	—38,732	—68,733 in 1900
1900–1910	53,285	5.65	295,448	29.18	—242,163	—310,896 in 1910
Totals	603,876	....	1,262,196	......	—658,320	....

* Minus sign (—) denotes decrease.

TABLE CDXXXII. POPULATION OF CHICAGO, CLASSIFIED BY PLACE OF BIRTH, 1850-1910

Year	Total Population	Native-Born				Foreign-Born	
		Born in Illinois	Per Cent of Total Population	Born in Other States	Per Cent of Total Population	Total Number	Per Cent of Total Population
1	2	3	4	5	6	7	8
1850	29,375	5,831	19.85	7,862	26.76	15,682	53.39
1860	109,260	28,093	25.71	26,543	24.29	54,624	50.00
1870	298,977	87,991	29.43	66,429	22.22	144,557	48.35
1880	503,185	197,728	39.30	100,598	19.99	204,859	40.71
1890	1,099,850	436,430	39.68	212,754	19.34	450,666	40.98
1900	1,698,575	769,882	45.33	341,581	20.11	587,112	34.56
1910	2,185,283	1,017,495	46.56	384,360	17.59	783,428	35.85

TABLE CDXXXIII. RATIO OF INCREASE IN TOTAL POPULATION OF CHICAGO. 1850-1910

1850	1860	1870	1880	1890	1900	1910
1	2	3	4	5	6	7
1.00	3.72	10.18	17.13	37.44	57.82	74.39
	1.00	2.74	4.61	10.07	15.55	20.00
		1.00	1.68	3.68	5.68	7.31
			1.00	2.19	3.38	4.34
				1.00	1.54	1.99
					1.00	1.29

TABLE CDXXXIV. RATIO OF INCREASE IN POPULATION OF CHICAGO BORN IN ILLINOIS. 1850-1910

1850	1860	1870	1880	1890	1900	1910
1	2	3	4	5	6	7
1.00	4.82	15.09	33.91	74.85	132.03	174.50
	1.00	3.13	7.04	15.54	27.40	36.22
		1.00	2.25	4.96	8.75	11.56
			1.00	2.21	3.89	5.15
				1.00	1.76	2.33
					1.00	1.32

TABLE CDXXXV. RATIO OF INCREASE IN NATIVE-BORN POPULATION OF OTHER STATES LIVING IN CHICAGO. 1850-1910

1850	1860	1870	1880	1890	1900	1910
1	2	3	4	5	6	7
1.00	3.38	8.45	12.80	27.06	43.45	48.89
	1.00	2.50	3.79	8.02	12.87	14.48
		1.00	1.51	3.20	5.14	5.79
			1.00	2.11	3.40	3.82
				1.00	1.61	1.81
					1.00	1.13

TABLE CDXXXVI. RATIO OF INCREASE IN FOREIGN-BORN POPULATION OF CHICAGO. 1850-1910

1850	1860	1870	1880	1890	1900	1910
1	2	3	4	5	6	7
1.00	3.48	9.22	13.06	28.74	37.44	49.96
	1.00	2.65	3.75	8.25	10.75	14.34
		1.00	1.42	3.12	4.06	5.42
			1.00	2.20	2.87	3.82
				1.00	1.30	1.74
					1.00	1.33

TABLE CDXXXVII. AVERAGE DECENNIAL PERCENTAGE OF INCREASE IN POPULATION OF CHICAGO, 1850-1910

Decade	Total	Illinois-Born	Native-Born of Other States	Foreign-Born
1	2	3	4	5
1850-1910	105.08	136.39	91.22	91.91
1860-1910	82.06	105.02	70.67	70.34
1870-1910	64.42	84.41	55.09	52.58
1880-1910	63.15	72.65	56.33	56.38
1890-1910	40.96	52.69	34.41	31.85
1900-1910	28.65	32.16	12.52	33.44

TABLE CDXXXVIII. SUCCESSIVE DECENNIAL PERCENTAGE OF INCREASE IN POPULATION OF CHICAGO. 1850-1910

Decade	Total	Illinois-Born	Native-Born of Other States	Foreign-Born
1	2	3	4	5
1850-1860	271.95	381.79	237.61	(Not given)
1860-1870	173.64	213.21	150.27	
1870-1880	68.30	124.71	51.44	
1880-1890	118.58	120.72	111.49	
1890-1900	54.44	76.40	60.55	
1900-1910	28.65	32.16	12.52	

the total population of the city, while in 1910 the foreign-born population represented but 35.85 per cent of the total. The native-born, representing 46.61 per cent of the population in 1850, had increased in 1910 to 64.15 per cent of the population.

Still another change is noteworthy in connection with the relative proportion of the population of Chicago born in Illinois and that born in other states. The proportion of the total of those born in Illinois increased from 19.85 per cent in 1850 to 46.56 per cent in 1910, while the proportion, to the total, of the population born in other states, like that of the foreign-born population, has been decreasing, having been 26.76 per cent in 1850 and 17.59 per cent in 1910. The increase of population in Chicago is becoming more and more dependent upon the proportion of its population born in Illinois.

701.07 Statistics of Migration: The three decades from 1870 to 1900 may be noted as contributing special influences on the population of Chicago. The first includes the great fire; from 1880 to 1890, the urban movement rose to its highest proportions; and the World's Fair of 1893 affected the decade from 1890 to 1900. The significance of these facts is shown by tables CDXXXIX to CDXLI, inclusive.

TABLE CDXXXIX. COMPARISON OF POPULATION BORN IN OTHER STATES LIVING IN CHICAGO, AND IN ILLINOIS EXCLUSIVE OF CHICAGO, 1850-1910

Year	Total Population Born in Other States Living in Illinois	Living in Chicago		Living in Illinois Outside of Chicago	
		Total Number	Per Cent of Total Number Living in Illinois	Total Number	Per Cent of Total Number Living in Illinois
1	2	3	4	5	6
1850	393,313	7,862	2.00	385,451	98.00
1860	680,383	26,543	3.90	653,840	96.10
1870	835,190	66,429	7.95	768,761	92.05
1880	784,775	100,598	12.82	684,177	87.18
1890	787,716	212,754	27.01	574,962	72.99
1900	943,904	341,581	36.19	602,323	63.81
1910	997,189	384,360	38.54	612,829	61.46

TABLE CDXL. POPULATION BORN IN OTHER STATES LIVING IN ILLINOIS. 1850-1910

Year	Ratio of Increase or Decrease	Average Decennial Percentage Increase		Actual Successive Decennial Percentage Increase or Decrease	
		Period	Per Cent	Decade	Per Cent
1	2	3	4	5	6
1850	1.00	1850-1910	16.77	1850-1860	72.99
1860	1.73 1.00	1860-1910	7.95	1860-1870	22.75
1870	2.12 1.23 1.00	1870-1910	4.53	1870-1880	—6.04*
1880	2.00 1.15 0.94 1.00	1880-1910	8.31	1880-1890	0.37
1890	2.00 1.16 0.94 1.00 1.00	1890-1910	12.51	1890-1900	19.83
1900	2.40 1.39 1.13 1.20 1.20 1.00	1900-1910	5.65	1900-1910	5.65
1910	2.54 1.47 1.19 1.27 1.27 1.06				

TABLE CDXLI. POPULATION BORN IN OTHER STATES LIVING IN ILLINOIS EXCLUSIVE OF CHICAGO, 1850-1910

Year	Ratio of Increase or Decrease	Average Decennial Percentage Increase or Decrease		Actual Successive Decennial Percentage Increase or Decrease	
		Period	Per Cent	Decade	Per Cent
1	2	3	4	5	6
1850	1.00	1850-1910	8.03	1850-1860	69.63
1860	1.70 1.00	1860-1910	—1.29*	1860-1870	17.58
1870	1.99 1.18 1.00	1870-1910	—5.51	1870-1880	—11.00
1880	1.78 1.05 0.89 1.00	1880-1910	—3.60	1880-1890	—15.96
1890	1.49 0.88 0.75 0.84 1.00	1890-1910	3.24	1890-1900	4.76
1900	1.56 0.92 0.78 0.88 1.05 1.00	1900-1910	1.74	1900-1910	1.74
1910	1.59 0.94 0.80 0.90 1.07 1.02				

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* Minus sign (—) denotes decrease.

701.08 Decennial Comparison of Population Born in Other States and Living in Chicago, and Population Born in Other States and Living in Illinois Exclusive of Chicago: A comparison of the population born in other states, living in Chicago and in Illinois exclusive of Chicago, for the census years 1850 to 1910, inclusive, is presented in tables CDXXXIX to CDXLI, inclusive.

A noticeable change has taken place in the distribution of persons migrating from other states. In 1850, of the total population born in other states and living in Illinois, only 2.00 per cent were living in Chicago, while 98.00 per cent were living in Illinois exclusive of Chicago. In 1910, the conditions had so changed that of those who had migrated to Illinois from other states, 38.54 per cent were living in Chicago and 61.46 per cent were living in Illinois exclusive of Chicago.

Between the years 1850 and 1910, the population which migrated from other states to Illinois increased 250 per cent. During the same period that part of the migrated population living in Illinois exclusive of Chicago increased about 60 per cent; but the greatest increase appears in the number of the native-born persons of other states living in Chicago, the number in 1910 being 48.89 times that in 1850.

701.09 Comparison of Native-Born and Foreign-Born Population of Illinois and of Chicago: A comparison of the native-born and the foreign-born population of Illinois and of Chicago, by census years from 1850 to 1910, is shown in table CDXLII.

Of the total population of Illinois in 1850, 86.55 per cent were of native birth, while the remaining 13.45 per cent were of foreign birth. In 1910 the native-born population of the state represented 78.62 per cent of the total population, and the foreign-born accounted for the remaining 21.38 per cent.

Of the total population of Chicago in 1850, 46.61 per cent were native-born, while 53.39 per cent were foreign-born. In 1910, the native-born represented 64.15 per cent, while the foreign-born represented 35.85 per cent of the total population.

Of the population of Illinois exclusive of Chicago in 1850, 87.97 per cent were native-born and 12.03 per cent were foreign-born. Of the population of Illinois exclusive of Chicago in 1910, 87.78 per cent were native-born and 12.22 per cent were foreign-born.

In 1850, Chicago's population represented 3.45 per cent of the total population of the state. In 1860, it was 6.38 per cent; in 1870, 11.77 per cent; in 1880, 16.35 per cent; in 1890, 28.74 per cent; in 1900, 35.23 per cent; and in 1910, 38.76 per cent. The average decennial increase for the state from 1850 to 1910 was 36.91 per cent and the corresponding rate for Chicago was 105.08 per cent.

The total native-born population of Illinois, beginning with the decade 1850 to 1860, shows successive decennial percentage increases of 88.25, 45.94, 23.19, 19.63, 29.18 and 15.01.

In 1850, of the native-born population of Illinois, Chicago claimed but 1.86 per cent, and the remaining 98.14 per cent were located in other parts of the state. In 1910, of the native-born population, Chicago had 31.62 per cent, and the remaining 68.38 per cent were located in other parts of the state.

701.10 Comparison of Foreign-Born Population of Illinois, Cook County and Chicago: A comparison of the totals and percentages of the foreign-born population of Illinois, Cook County and Chicago is presented by table CDXLIII.

Of the total foreign-born population of Illinois in 1850, 19.09 per cent were in Cook County and 80.91 per cent were in other parts of the state. In 1900, 64.74 per cent of the total were located in Cook County and 35.26 per cent in other parts of Illinois. Chicago itself claimed most of the foreign-born population of Cook County, as will be seen by a comparison of the county and city figures for the same census years. In 1850, Chicago had 13.69 per cent of the total foreign-born population of the state, while in 1910 it had 65 per cent of such population.

The foreign-born population of Cook County exclusive of Chicago increased from 6,181 in 1850 to 38,772 in 1900. These figures have been used as a guide in determining the proportion of foreign-born added to the population of Chicago from time to time through annexations. The decrease in the foreign-born population living in Cook County exclusive of Chicago during the decade 1880–1890, was due to the large annexations to Chicago made during this period.

701.11 Comparative Increase in Total and Native-Born Population of Illinois, Cook County and Chicago: The comparative increases in the native-born and foreign-born population of Illinois, Cook County and Chicago for the six decennial periods previous to 1910 are shown by table CDXLIV.

The total population of Illinois in 1910 was 6.62 times that in 1850. The average compound decennial increase for this period has already been referred to as 36.91 per cent.

The total population of Chicago in 1910 was 74.39 times as great as in 1850. The average decennial increase from 1850 to 1910 amounted to 105.08 per

TABLE CDXLII. COMPARISON OF NATIVE-BORN AND FOREIGN-BORN POPULATION OF ILLINOIS AND OF CHICAGO
1850-1910

Year	Total Population		Native-Born Population				Foreign-Born Population			
	Illinois	Chicago	Total	Per Cent of Total Population	Living in Chicago	Living in Other Parts of Illinois	Total	Per Cent of Total Population	Living in Chicago	Living in Other Parts of Illinois
1	2	3	4	5	6	7	8	9	10	11
1850	851,470	29,375	736,931	86.55	13,693	723,238	114,539	13.45	15,682	98,857
1860	1,711,951	109,260	1,387,308	81.04	54,636	1,332,672	324,643	18.96	54,624	270,019
1870	2,539,891	298,977	2,024,693	79.72	154,420	1,870,273	515,198	20.28	144,557	370,641
1880	3,077,871	503,185	2,494,295	81.04	298,326	2,195,969	583,576	18.96	204,859	378,717
1890	3,826,351	1,099,850	2,984,004	77.99	649,184	2,334,820	842,347	22.01	450,666	391,681
1900	4,821,550	1,698,575	3,854,803	79.95	1,111,463	2,743,340	966,747	20.05	587,112	379,635
1910	5,638,591	2,185,283	4,433,277	78.62	1,401,855	3,031,422	1,205,314	21.38	783,428	421,886

TABLE CDXLIII. COMPARISON OF FOREIGN-BORN POPULATION OF ILLINOIS, COOK COUNTY AND CHICAGO, 1850-1910

Year	Illinois	Cook County		Illinois, Exclusive of Cook County		Chicago		Illinois, Exclusive of Chicago		Cook County, Exclusive of Chicago	
		Total	Per Cent of Total Foreign-Born Population of Illinois	Total	Per Cent of Total Foreign-Born Population of Illinois	Total	Per Cent of Total Foreign-Born Population of Illinois	Total	Per Cent of Total Foreign-Born Population of Illinois	Total	Per Cent of Total Foreign-Born Population of Cook Co.
1	2	3	4	5	6	7	8	9	10	11	12
1850	114,539	12,863	19.09	92,676	80.91	15,682	13.69	98,857	86.31	6,181	5.40
1860	324,643	71,873	22.14	252,770	77.86	54,624	16.83	270,019	83.17	17,249	5.31
1870	515,198	166,772	32.37	348,426	67.63	144,557	28.06	370,641	71.94	22,215	4.31
1880	583,576	242,415	41.54	341,161	58.46	204,859	35.10	378,717	64.90	37,556	6.44
1890	842,347	482,652	57.30	359,695	42.70	450,666	53.50	391,681	46.50	31,986	3.80
1900	966,747	625,884	64.74	340,863	35.26	587,112	60.73	379,635	39.27	38,772	4.01
1910	1,205,314	844,874	.....	360,440	.....	783,428	65.00	421,886	35.00	61,446	....

cent. The average decennial increase in the population of Cook County from 1850 to 1910 amounted to 95.27 per cent.

The total native-born population of Illinois in 1910 was 6.02 times that of 1850. The native-born population of Chicago in 1910 was 102.38 times as great as in 1850.

Corresponding figures for the increases in the native population of Cook County, as compared with the increases for Illinois, do not vary greatly from the comparison of the figures for Chicago and the state. Both, however, reached a maximum relation in the decade from 1880 to 1890, after which their proportion to the increases of the state was less.

701.12 Comparative Increase in Foreign-Born Population of Illinois, Cook County and Chicago: The comparative increases in the foreign-born population of Illinois as a whole, of Chicago, of Illinois exclusive of Chicago, and of Cook County and Cook County exclusive of Chicago, are presented in table CDXLV.

In 1910 the foreign-born population of Illinois was 10.52 times as great as in 1850. The successive decennial increases have been previously noted. In the decade from 1890 to 1900, Chicago's increase in foreign-born population was greater than that of the state. In 1910 Illinois exclusive of Chicago had gained in foreign-born population 4.27 times the foreign-born population of 1850.

701.13 Comparative Increase in Native-Born and Foreign-Born Population of Chicago: Statistics of comparative increases in the native-born and the foreign-born population of Chicago are presented in table CDXLVI.

In connection with the facts shown by table CDXLVI, attention is again called to the special influences of the three decades from 1870 to 1900, including respectively the Chicago fire of 1871, the great urban movement and the World's Fair of 1893.

While the increases for the entire city have been decreasing in percentage relation to previous years, they have been increasing in numerical proportion, with the exception of the decade from 1900 to 1910 as compared with that from 1890 to 1900.

The increase in native population forms an increasing proportion of the total increases for the city, ranging from 51.3 per cent in the earliest decade to 59.7 per cent in the latest. The complement of these figures is seen in the relation of the increases of the foreign-born, varying from 48.7 to 40.3 per cent.

In subdividing the increases of the native-born population, it will be observed that the increase of those born in Illinois has advanced from 27.9 to 50.9 per cent, while the increase of those born in other states has declined from 23.4 to 8.8 per cent.

701.14 Increase in the Foreign-Born Population of Chicago, Grouped by Leading Race or Country of Birth: The increase in the foreign-born population of Chicago, grouped by leading races, is shown by table CDXLVII, covering the decades from 1880 to 1910.

In reviewing the racial increases for these three decades, it is well to bear in mind that the statistics are the resultant, on the one hand, of the positive influence of population increase of foreign-born due to

TABLE CDXLIV. COMPARATIVE INCREASE IN TOTAL AND NATIVE-BORN POPULATION OF ILLINOIS, COOK COUNTY AND CHICAGO, 1850-1910

Decade	Increase in the Population, both Native-Born and Foreign-Born						Increase in the Native-Born Population					
	Illinois		Chicago		Cook County		Illinois		Chicago		Cook County (Including Chicago)	
	Total	Per Cent of Increase	Total	Per Cent of Increase	Total	Per Cent of Increase	Total	Per Cent of Increase	Total	Per Cent of Total Increase for Illinois	Total	Per Cent of Total Increase for Illinois
1	2	3	4	5	6	7	8	9	10	11	12	13
1850-1860	860,481	101.06	79,885	271.95	101,569	234.11	630,377	88.25	40,943	6.29	51,559	7.92
1860-1870	827,940	48.36	189,717	173.64	205,012	141.43	637,385	45.94	99,784	15.66	110,113	17.28
1870-1880	537,980	21.18	204,208	68.30	257,558	73.00	469,602	23.19	143,906	30.64	181,915	38.74
1880-1890	748,480	24.32	596,665	118.58	584,398	96.19	489,709	19.63	350,858	71.65	344,161	70.28
1890-1900	995,199	26.01	598,725	54.44	646,813	54.27	870,799	29.18	462,279	53.09	503,581	57.83
1900-1910	817,041	16.95	486,708	28.65	566,498	30.81	578,474	15.01	290,392	50.20	......	.....
Totals	4,787,121		2,155,908	.....	2,361,848		3,696,346	. . .	1,388,162	.....	......	......

TABLE CDXLV. COMPARATIVE INCREASES IN THE FOREIGN-BORN POPULATION OF ILLINOIS, COOK COUNTY AND CHICAGO, 1850-1910

Decade	Illinois		Chicago		Illinois Exclusive of Chicago		Cook County		Cook County Exclusive of Chicago	
	Total	Per Cent of Increase	Total	Per Cent of Total Increase for Illinois	Total	Per Cent of Total Increase for Illinois	Total	Per Cent of Total Increase for Illinois	Total	Per Cent of Total Increase for Illinois
1	2	3	4	5	6	7	8	9	10	11
1850–1860	210,104	183.44	38,912	18.53	171,162	81.47	50,010	23.80	11,068	5.27
1860–1870	190,555	58.70	89,933	47.20	100,622	52.80	94,899	49.80	4,966	2.60
1870–1880	68,378	13.27	60,302	88.19	8,076	11.81	75,643	110.62	15,341	22.43
1880–1890	258,771	44.34	245,807	94.99	12,964	5.01	240,237	92.84	—5,570	—2.15
1890–1900	124,400	14.77	136,446	109.68	—12,046*	—9.68	143,232	115.13	6,786	5.45
1900–1910	238,567	24.68	196,316	82.29	42,251	17.71	....	....	....	....
Totals	1,090,775	100.00	767,746	70.39	323,029	29.61	....	....	....	....

* Minus sign (—) denotes decrease.

immigration and migration and, on the other hand, of the negative influence of population decrease due to emigration, migration to other states and death of foreign-born. The most important changes are to be noted in the decreasing proportion of the Germanic and English influx. From 1880 to 1890, the Germanic showed a large increase, and a considerable one in the next decade, 1890 to 1900; but from 1900 to 1910, there was an actual loss representing the difference between the total loss through death, migration to other states or other parts of Illinois, and emigration, and the total gain through immigration and migration from other states or other parts of Illinois.

In like manner, the first two decades, 1880 to 1890 and 1890 to 1900, saw an increase from Great Britain, Ireland and the Colonies, while the last decade, 1900 to 1910, showed a loss. The Scandinavian element also shows a successive decline through these three decades.

These deficiencies are in part made up by the Slavonic and Latin increases for the three decades. No less striking than the foregoing is the decline in the increase of the foreign-born population as a whole.

701.15 Immigration to and Emigration from the United States of Aliens, by Classes: Statistics of immigration to and emigration from the United States of aliens, grouped by classes, are presented by table CDXLVIII, for the years 1908 to 1912, inclusive. These statistics are based upon information supplied by the records of the Bureau of Immigration, which, since the year 1908, has collected statistics of the arrival and departure of aliens, classifying those arriving and departing as immigrant and non-immigrant aliens.

Arriving aliens, whose permanent residence has been outside the United States and who intend to reside permanently in the United States, are classed as immigrant aliens. Departing aliens, whose permanent residence has been in the United States and who intend to reside permanently elsewhere, are classed as emigrant aliens.

All aliens, residents of the United States, making a temporary trip abroad, and all aliens, residing abroad, making a temporary trip to the United States, are classed as non-immigrant aliens on the inward journey and as non-emigrant aliens on the outward journey. Continuous residence for one year or more is considered as permanent residence and for a less time as temporary residence.

A disturbing factor is introduced into the statistics of non-immigrant aliens because a certain number of immigrant aliens make a change in their plans by returning to their native homes within a year after arrival, although on admission to the United States they had declared the intention of residing permanently in the United States. Since such aliens are classed as immigrant aliens on their arrival and as non-emigrant aliens on their departure, it is evident that the number of non-emigrant aliens tends always to be larger than the number of non-immigrant aliens.

701.16 Immigration to and Emigration from the United States of Aliens, by Five-Year Periods: Statistics of immigration to and emigration from the United States of aliens, by five-year periods from 1898 to 1912, are given in table CDXLIX. These statistics, including both arrivals and departures of aliens, are taken from the records of the Immigration Service of the federal government and cover the fiscal

TABLE CDXLVI. COMPARATIVE INCREASE IN NATIVE-BORN AND FOREIGN-BORN POPULATION OF CHICAGO, 1850-1910

Decade	Total Increase in Population	Per Cent of Increase	Increase in Native-Born Population						Increase in Foreign-Born Population	
			Total	Per Cent of Total Increase in Population	Born in Illinois	Per Cent of Total Increase in Population	Born in Other States	Per Cent of Total Increase in Population	Total	Per Cent of Total Increase in Population
1	2	3	4	5	6	7	8	9	10	11
1850–1860	79,885	272.0	40,943	51.3	22,262	27.9	18,681	23.4	38,942	48.7
1860–1870	189,717	173.6	99,784	52.6	59,898	31.6	39,886	21.0	89,933	47.4
1870–1880	204,208	68.3	143,906	70.5	109,737	53.8	34,169	16.7	60,302	29.5
1880–1890	596,665	118.6	350,858	58.8	238,702	40.0	112,156	18.8	245,807	41.2
1890–1900	598,725	54.4	462,279	77.2	333,452	55.7	128,827	21.5	136,446	22.8
1900–1910	486,708	28.7	290,392	59.7	247,613	50.9	42,779	8.8	196,316	40.3
Totals	2,155,908	.....	1,388,162	64.4	1,011,664	46.9	376,498	17.5	767,746	35.6

TABLE CDXLVII. INCREASE IN THE FOREIGN-BORN POPULATION OF CHICAGO, GROUPED BY LEADING RACE OR COUNTRY OF BIRTH, 1880-1910

Race	Population in 1910		Increase 1900–1910		Increase 1890–1900		Increase 1880–1890	
	Total	Per Cent of Total Foreign-Born	Total	Per Cent of Increase	Total	Per Cent of Increase	Total	Per Cent of Increase
1	2	3	4	5	6	7	8	9
Slav	286,646	36.59	184,533	94.00	37,378	27.39	44,735	18.21
Germanic	198,080	25.28	—18,619*	—9.48	47,075	34.50	90,073	36.67
Scandinavian	99,896	12.75	8,467	4.31	19,475	14.27	46,685	19.00
Latin	55,250	7.05	34,499	17.57	12,003	8.80	5,608	2.28
Great Britain, Ireland and Colonies	137,322	17.53	—12,842	—6.54	16,464	12.07	57,349	23.34
Turkey	1,886	0.24	1,706	0.87	155	0.11	11	0.01
Colored	1,948	0.25	463	0.23	624	0.46	337	0.14
All other	2,400	0.31	—1,891	—0.96	3,272	2.40	865	0.35
Totals	783,428	100.00	196,316	82.29	136,446	109.68	245,663	94.99

* Minus sign (—) denotes decrease.

year ending June 30. Prior to 1908, no records of the departure of aliens were kept by the national government.

The statistics of departures for the two preceding five-year periods were calculated from figures supplied by the Trans-Atlantic Passenger Conference, which show the number of arrivals and departures of steerage passengers, including both aliens and citizens of the United States traveling in steerage. These statistics cover the calendar years from 1898 to 1902, and from 1903 to 1907.

In accepting the statistics of the Trans-Atlantic Passenger Conference, it was assumed that the total arrivals and departures, both steerage and cabin, would bear about the same ratio to one another as did the arrivals and departures of steerage passengers, and that this would be approximately correct for all alien passenger traffic outside of that of the Trans-Atlantic Passenger Conference.

The statistics for the period 1898 to 1902 refer to aliens arriving or departing as steerage passengers only, no record having been kept by the federal government at the time.

From examination of table CDXLIX, it appears that there is an increasing tendency on the part of the foreign-born to return to the country of their nativity. Of the total number admitted from 1898 to 1902, 30.44 per cent left the United States and the remaining 69.56 per cent constituted the net increase in population due to immigration. Of those admitted from 1908 to 1912, 51.41 per cent departed again and the remaining 48.59 per cent settled in this country.

701.17 Length of Residence in the United States of Emigrant Aliens who Departed during the Years 1908 to 1912: Statistics of length of residence in the United States of emigrant aliens who left the country during the years 1908 to 1912, are given in table CDL.

The information contained in table CDL has been derived from the records of the Federal Bureau of Immigration. For a certain small percentage (about ten per cent) of all emigrant aliens, the length of residence is, for one reason or another, not apparent. Such aliens are reported by the Bureau of Immigration under the caption "residence unknown." Therefore, this class of aliens has been distributed proportionately to the three groups for which the length of residence is known, in order that a more accurate basis might be provided for the determination of the percentage which the departures during each of the three periods indicated bore to the total arrivals.

From these figures, it will be observed that the departures of those whose length of residence has not exceeded ten years bear the greatest proportion to the total arrivals.

701.18 Aliens who on Admittance Declared Illinois to be their Destination, and in Departing Declared Illinois to have been their Last Permanent Residence: Statistics relating to aliens who declared Illinois their destination, and to those who on their departure declared Illinois to have been their residence, are presented in table CDLI.

The increase in the ratio of total departures to total arrivals, as shown in table CDLI, further emphasizes the tendency of foreign-born persons to return to the land of their birth.

TABLE CDXLVIII. IMMIGRATION TO AND EMIGRATION FROM THE UNITED STATES OF ALIENS, BY CLASSES, 1908-1912

Year	Immigration into the United States					Total Emigration	Emigration from the United States				Net Increase in Population	
	Total Immigration	Immigrant Aliens Admitted		Non-Immigrant Aliens Admitted			Emigrant Aliens Who Departed		Non-Emigrant Aliens Who Departed			
		Total Number	Per Cent of Total Immigration	Total Number	Per Cent of Total Immigration		Total Number	Per Cent of Total Emigration	Total Number	Per Cent of Total Emigration	Tota	Per Cent of Total Immigration
1	2	3	4	5	6	7	8	9	10	11	12	13
1908	924,695	782,870	84.66	141,825	15.34	714,828	395,073	55.27	319,755	44.73	209,867	22.70
1909	944,235	751,786	79.62	192,449	20.38	400,392	225,802	56.40	174,590	43.60	543,843	57.60
1910	1,198,037	1,041,570	86.94	156,467	13.06	380,418	202,436	53.21	177,982	46.79	817,619	68.25
1911	1,030,300	878,587	85.27	151,713	14.73	518,215	295,666	57.05	222,549	42.95	512,085	49.70
1912	1,017,155	838,172	82.40	178,983	17.60	615,292	333,262	54.16	282,030	45.84	401,863	39.51
Totals	5,114,422	4,292,985	83.94	821,437	16.06	2,629,145	1,452,239	55.24	1,176,906	44.76	2,485,277	48.59

701.19 Movement of Foreign-Born Population of Chicago by Decades of Arrival in the United States: Statistics relating to the movement of the foreign-born population of Chicago, from 1880 to 1910, are given in tables CDLII to CDLIV, inclusive.

According to table CDL, 1.05 per cent of all foreign-born departed from the United States within 10 to 20 years after arrival. On this basis, the emigration of this class of foreign-born was approximately 1,448. By deducting the loss through death and through emigration, the number of this class of foreign-born living in Chicago in 1910 was 121,667. As a matter of fact, however, the census of 1910 showed (table CDLIII) 141,302 foreign-born living in Chicago who had arrived in the United States during the decade 1890 to 1900. It is evident from this that there must have been a net increase through migration to the city of 19,635 of this class of foreign-born in order to bring the number resident in the city in 1910 up to the number found resident there at the time of the census.

In view of the loss in population of this class during the decade 1900 to 1910, of 23,174 through emigration or death, the net result for the decade in the movement of this class was a decrease of 3,539.

As to the movement of foreign-born who arrived in the United States prior to 1890, it is known that 442,271 were living in Chicago in 1900. The minimum age of this class was 10 years in 1900. The loss by death of persons less than 10 years of age, who constitute 22.2 per cent of the total population according to the mortality statistics published by the United States Census, is 29.21 per cent. It follows that the death rate for foreign-born over 10 years of age is somewhat below the average rate of 15 per 1,000 which obtains for the population of all ages. This rate was, however, applied as a conservative measure of deaths among this class.

According to table CDL, 0.33 per cent of all foreign-born emigrate after a residence in the United States of over 20 years, and on this basis 1,415 foreign-born persons of this class emigrated during the decade 1900 to 1910.

By deducting the loss through death and emigration, the number of this class of foreign-born living in Chicago in 1910 is found to be 374,515. But the census of 1910 shows 331,297 foreign-born living in Chicago who had arrived in the United States prior to 1900. It is evident from this that there must have been a net

TABLE CDXLIX. IMMIGRATION TO AND EMIGRATION FROM THE UNITED STATES OF ALIENS, BY FIVE-YEAR PERIODS
1898-1912

Period	Admitted	Departed		Net Increase in Population Due to Immigration	Per Cent of Total Number Admitted
		Total	Per Cent of Total Number Admitted		
1	2	3	4	5	6
1898–1902	2,350,713	715,571	30.44	1,635,142	69.56
1898–1907	7,699,785	2,612,622	33.93	5,087,163	66.07
1903–1907	5,349,072	1,897,051	35.47	3,452,021	64.53
1903–1912	10,463,494	4,526,196	43.26	5,937,298	56.74
1908–1912	5,114,422	2,629,145	51.41	2,485,277	48.59
Totals	12,814,207	5,241,767	40.91	7,572,440	59.09

TABLE CDL. LENGTH OF RESIDENCE IN THE UNITED STATES OF EMIGRANT ALIENS WHO DEPARTED DURING THE YEARS
1908-1912

Year	Total Arrivals	Total Departures	Residence Not Over Ten Years		Residence of from Ten to Twenty Years		Residence Over Twenty Years	
			Total Departures	Per Cent of Total Arrivals	Total Departures	Per Cent of Total Arrivals	Total Departures	Per Cent of Total Arrivals
1	2	3	4	5	6	7	8	9
1908	782,870	395,073	383,516	48.99	8,899	1.14	2,658	0.34
1909	751,786	225,802	215,472	28.66	7,706	1.03	2,624	0.35
1910	1,041,570	202,436	192,499	18.48	7,440	0.71	2,497	0.24
1911	878,587	295,666	283,714	32.29	8,905	1.01	3,047	0.35
1912	838,172	333,262	317,989	37.94	11,976	1.43	3,297	0.39
Totals	4,292,985	1,452,239	1,393,190	32.45	44,926	1.05	14,123	0.33

TABLE CDLI. LENGTH OF RESIDENCE IN ILLINOIS OF EMIGRANT ALIENS WHO DEPARTED DURING THE YEARS
1909-1912

Year	Aliens who on Admittance Declared Illinois to be their Destination			Aliens who in Departing Declared Illinois to have been their Last Permanent Residence			
	Immigrant Aliens	Non-Immigrant Aliens	Total Arrivals in Illinois	Emigrant Aliens	Non-Emigrant Aliens	Total Departures from Illinois	Per Cent of Total Arrivals in Illinois
1	2	3	4	5	6	7	8
1909	63,379	9,797	73,176	14,485	5,186	19,671	26.9
1910	93,340	6,457	99,797	13,165	6,955	20,120	20.2
1911	76,565	5,733	82,298	21,157	8,974	30,131	36.6
1912	67,118	5,919	73,037	28,355	11,796	40,151	55.0
Totals	300,402	27,906	328,308	77,162	32,911	110,073	33.5

decrease through migration from the city of 43,218 of this class of foreign born.

The total decrease in foreign-born who had arrived in the United States prior to 1890 was 110,974.

A certain percentage of the foreign-born did not report to the Census Bureau the decade of their arrival in the United States. These are classified in table CDLIII under "Date of arrival unknown." In order that the total foreign-born population living in Chicago in each census year might be accounted for, the number of those whose date of arrival was unknown was prorated among the several groups whose arrival was known, the grand total for each group also being presented in table CDLIII.

701.20 Movement of Immigrants who Arrived in Illinois and in Chicago, 1890 to 1910: The statistics relating to immigration to Illinois, as presented in table CDLIV, were taken from the annual reports of the Federal Bureau of Immigration, which requires immigrants to name the state of intended future residence. The accuracy of these figures has at times been questioned, because of the apparent lack of relationship between the number of immigrants declaring their intention of future residence in a particular state and the actual increase in foreign-born in that state as shown by the census. The totals here presented, however, apparently establish the approximate accuracy of the immigration statistics.

In pro-rating the total immigration to Illinois between Chicago and the rest of the state for each decade, the relative increase in foreign-born for each geographical area was taken as a measure. As shown by table CDXLV, this increase was 82.29 per cent for Chicago and 17.71 per cent for Illinois exclusive of Chicago, during the decade 1900 to 1910. As shown by the same table, the state of Illinois exclusive of Chicago, during the decade 1890 to 1900, suffered a net loss in foreign-born of 9.68 per cent or 12,046. Had there been no immigration to this area during this decade, the total loss from death alone, on the basis of 15 per 1,000, would have been 57,849. It is evident, therefore, that at least 45,803 foreign-born settled in this area during the decade.

The number of immigrants who located in Chicago, and later in the decade returned to a foreign country, was estimated from information as to the total arrivals and departures of immigrants contained in the annual reports of the Federal Immigration Service. The statistics (tables CDXLIX to CDLI) do not cover an entire decade, as a record of departures of aliens was not kept prior to the year 1908. The departures for earlier years have, however, been closely

TABLE CDLII. MOVEMENT OF FOREIGN-BORN POPULATION OF CHICAGO, BY DECADES OF ARRIVAL IN THE UNITED STATES 1901-1910

Decade of Arrival in the United States	Increase in Foreign-Born			Decrease in Foreign-Born				Net Increase or Decrease
	Total Increase	Increase Due to Immigration	Increase Due to Migration	Total Decrease	Decrease Due to Emigration	Decrease Due to Migration	Decrease Due to Death	
1	2	3	4	5	6	7	8	9
Prior to 1890	......	......	......	110,974	1,415	43,218	66,341	—110,974*
1890–1900	19,635	......	19,635	23,174	1,448	......	21,726	—3,539
1900–1910	567,768	567,768	......	256,939	184,525	43,671	28,743	310,829
Totals	587,403	567,768	19,635	391,087	187,388	86,889	116,810	196,316

* Minus sign (—) denotes decrease.

TABLE CDLIII. FOREIGN-BORN POPULATION OF CHICAGO, BY DECADES OF ARRIVAL IN THE UNITED STATES, 1880-1910

Decade of Arrival in United States	Census Year		Population after Proportional Distribution of the Class of Unknown			
	1910	1900	1910	Per Cent of Total Population	1900	Per Cent of Total Population
1	2	3	4	5	6	7
Date unknown	49,410	50,092	......	.....	......	.....
Prior to 1880	......	177,389	......	.....	193,934	33.03
1880–1890	......	227,148	......	.....	248,337	42.30
1890–1900	132,389	132,483	141,302	18.04	144,841	24.67
Prior to 1900	310,401	......	331,297	42.29	......	.....
1900–1910	291,228	......	310,829	39.67	......	.....
Totals	783,428	587,112	783,428	100.00	587,112	100.00

TABLE CDLIV. MOVEMENT OF IMMIGRANTS WHO ARRIVED IN ILLINOIS AND IN CHICAGO, BY DECADES OF ARRIVAL IN THE UNITED STATES, 1890-1910

Decade of Arrival in United States	Immigration to Illinois			Movement of Immigrants Who Located in Chicago				
	Total	To Chicago	To Illinois Exclusive of Chicago	Total	Number who Departed from the United States	Number who Died	Number who Migrated from Chicago	Number who were Living in Chicago at Close of Decade
1	2	3	1	5	6	7	8	9
1890–1900	268,302	210,885	57,417	210,885	43,231	12,495	10,318	144,841
1900–1910	692,400	567,768	124,632	567,768	184,525	28,743	43,671	310,829

TABLE CDLV. INCREASE IN POPULATION OF CHICAGO, BY SOURCES OF INCREASE, 1850-1910

Decade	Total Increase in Population	Increase in Native-Born					Increase in Foreign-Born			
		Total Increase	Due to Excess of Births over Deaths	Due to Migration		Due to Annexation	Total Increase	Due to Immigration	Due to Migration	Due to Annexation
				From other States	From other Parts of Illinois*					
1	2	3	4	5	6	7	8	9	10	11
1850–1860	79,885	40,913	7,971	18,681	14,291	....	38,942†	†	†	.....
1860–1870	189,717	99,784	23,474	39,886	32,083	4,341	89,933	85,869	†	4,064
1870–1880	204,208	143,906	46,124	34,169	63,613	....	60,302†	†	†	.....
1880–1890	596,665	350,858	78,406	112,156	19,021	141,275	245,807	147,632	†	98,175
1890–1900	598,725	462,279	160,667	128,827	160,013	12,772	136,446	140,525	—10,962‡	6,883
1900–1910	486,708	290,392	223,321	42,779	24,292	....	196,316	263,658	—67,342	.....
Totals	2,155,908	1,388,162	539,963	376,498	313,313	158,388	767,746	¶	¶	109,122

* The migration from other states, including as it does migration from outlying possessions, is to that extent less than the actual migration, and thus augments the migration figures given under this caption.
† No data available for segregation of total as to increase due to immigration and to migration.
‡ Migration of foreign-born who arrived during the decade 1890-1900. The total migration is not known.
¶ No complete data available.

approximated by the use of statistics furnished by the Trans-Atlantic Passenger Conference, as explained in connection with table CDLI.

Table CDLI shows that a number equal to 33.5 per cent of the total number of aliens, both immigrant and non-immigrant, who came to Illinois during the years 1909 to 1912, inclusive, departed from the United States during that period. Not all of those who departed had, however, arrived during the years 1909 to 1912. Table CDL shows that 32.45 per cent of all immigrant aliens who arrived in the country departed within the first decade after arrival. This percentage applies to emigration for the entire country. No statistics by states are kept which show the length of residence of aliens departing from the United States. From table CDXLVIII, it is evident that non-emigrant aliens constituted 44.76 per cent of the total emigration during the years 1908 to 1912.

Taking all the foregoing facts into consideration, it would seem that 32.45 per cent, which represents the relation of emigrant to immigrant aliens for the whole country and is the only definite figure available, may be taken as the average relationship between the total number of departures and the total number of arrivals of aliens in the state of Illinois during a given decade. This percentage is used in table CDLIV in determining the number of those aliens who arrived in Chicago during the decade and who left the United States within that decade.

701.21 Increase in Population of Chicago, by Sources of Increase: Statistics of increase in the population of Chicago, by decades and by sources of increase, are presented in table CDLV.

The statistics given in table CDLV are constructed in part from details taken from the foregoing tables. The excess of births over deaths was calculated on the basis of 11.5 per 1,000, the birth rate being taken as 26.5 and the death rate as 15 per 1,000. The rates are regarded as conservative when compared with the rates of such cities as Boston and New York. The birth rate assumed is probably slightly below, and the death rate slightly above, the actual rates for Chicago. In calculating the increase through natural causes by use of the factor 11.5, the average population for the decade was taken as a basis.

The segregation of the population annexed to the city, into native-born and foreign-born, was made on the basis of the rates which these two classes in the population of Chicago bore to one another in the census year nearest to the year of annexation. The total population annexed during each decade was determined as indicated in the statement of annexations (section 701.01).

The increase to Chicago through the migration of persons born in other states was derived as shown in tables CDXXX and CDXLVI. The increase through migration of persons born in Illinois was determined by deducting from the total increase in the population of Chicago born in Illinois, as shown in table CDXLVI, the increase within the city due to natural causes.

The data on the sources of increase of foreign-born are complete for the decades 1890 to 1900 and 1900 to

TABLE CDLVI. PERCENTAGE OF TOTAL INCREASE IN POPULATION OF CHICAGO DUE TO VARIOUS CAUSES, 1850-1910

Decade	Total Increase	Native-Born					Foreign-Born			
		Total	Excess of Births over Deaths	Migration		Annexation	Total	Immigration	Migration	Annexation
				From other States	From other Parts of Illinois					
1	2	3	4	5	6	7	8	9	10	11
1850–1860	271.95	51.25	9.98	23.38	17.89	.....	48.75	*	*	.....
1860–1870	173.64	52.60	12.37	21.03	16.91	2.29	47.40	45.26	*	2.14
1870–1880	68.30	70.47	22.59	16.73	31.15	.....	29.53	*	*	.....
1880–1890	118.58	58.80	13.14	18.79	3.19	23.68	41.20	24.74*	*	16.46
1890–1900	54.44	77.21	26.83	21.52	26.73	2.13	22.79	23.47	— 1.83†	1.15
1900–1910	28.65	59.66	45.88	8.79	4.99	.....	40.34	54.17	—13.83	.....
Totals	100.00	64.39	25.05	17.46	14.53	7.35	35.61	‡	‡	5.06

* No data available for segregation of total as to increase due to immigration and migration.
† Statistics limited to the migration of foreign-born who arrived during the decade 1890-1900. The total migration is not known.
‡ No complete data available.

TABLE CDLVII. INCREASES IN POPULATION OF CHICAGO, CLASSIFIED BY SOURCES OF INCREASE, 1850-1910

Decade	Total Increase in Population	Increase Due to					
		Natural Causes	Immigration and Migration of Foreign-Born	Migration of Native-Born	Annexation		
					Total	Native-Born	Foreign-Born
1	2	3	4	5	6	7	8
1850–1860	79,885	7,971	38,942	32,972	......	......	......
1860–1870	189,717	23,474	85,869	71,969	8,405	4,341	4,064
1870–1880	204,208	46,124	60,302	97,782	......	......	......
1880–1890	596,665	78,406	147,632	131,177	239,450	141,275	98,175
1890–1900	598,725	160,667	129,563	288,840	19,655	12,772	6,883
1900–1910	486,708	223,321	196,316	67,071	......	......	......
Totals	2,155,908	539,963	658,624	689,811	267,510	158,388	109,122

1910 only. No information is available for other decades, on the basis of which a segregation can be made of the total increase into that due to immigration and that due to migration of foreign-born.

701.22 Percentage of Total Increase in Population of Chicago, Due to Various Causes: The various percentage relations of the numbers appearing in table CDLV are shown in table CDLVI.

The changes in the proportion of native-born and foreign-born to these total increases have already been discussed. The former constituted 51.25 per cent of the total increase in the first decade and 59.66 per cent in the final decade, while the foreign-born represented 48.75 per cent in the first and 40.34 per cent in the last decade.

In the analysis of the increases of the native-born of Chicago for the past six decades, the excess of births over deaths was 25.05 per cent; the excess due to migration from other parts of Illinois, 14.53 per cent; while the other 7.35 per cent was due to annexation.

701.23 Increase in Population of Chicago, Classified by Sources of Increase: The increases in the population of Chicago, classified by sources of increase, are shown by table CDLVII.

Disregarding the effect of annexations in connection with the growth of Chicago's population, the principal source of increase, at least in the later decades, appears to be that arising from natural causes. This factor formed 9.98 per cent of the total increase in the opening decade and 45.88 per cent in the closing one.

From 1850 to 1860, the immigration and migration of foreign-born were responsible for a net increase of 48.75 per cent of the total increase, while from 1900 to 1910, the result of the movement was a net increase of 40.34 per cent of the total.

The net effect of the migration of native-born persons from 1850 to 1860 was the addition of 41.27 per cent of the total increase; from 1890 to 1900, this movement represented an addition of 48.25 per cent of the whole, while from 1900 to 1910, the increase was 13.78 per cent of the total. The large addition from 1890 to 1900 was greatly influenced by the World's Fair of 1893.

ESTIMATES OF FUTURE GROWTH IN THE POPULATION OF CHICAGO

701.24 Estimated Increase in the Future Population of Chicago, Classified by Sources of Increase: An estimate of the future increase in population of Chicago, classified by sources of increase and covering the decades 1910 to 1950, is presented in table CDLVIII. It may be assumed that the increase in the population of Chicago in the future, due to the migration of native-born from other states as well as from other parts of Illinois, will be considerably less than it has been in the past. Various positive influences are also at work which increase the stream of the rural movement and to a very marked extent offset the urban movement.

For these reasons the average increase due to migration from other states has been estimated at 30,000 for each decade, and that due to migration from other parts of Illinois at 85,000 for the decade 1910 to 1920, with a subsequent gradual decrease of 5,000 per decade for the succeeding decades.

Immigration, as a factor in the increase of the population of Chicago, will very probably also be a decreasing one, a fact due partly to the enactment of more stringent immigration laws by the United States, to the increase in the proportion of immigrants who locate in smaller cities and rural communities, and to the demand for industrial labor due to the establishment of large manufacturing concerns in outlying regions.

For these and other reasons, an estimated decrease of 25,000 per decade in the net increase due to the immigration and migration of foreign-born has been made.

Table CDLVIII has been made up in two separate parts, each in accordance with a different theory in regard to the birth rate. The upper portion of the statement has been developed with birth rate and death rate both decreasing, while the lower one, giving somewhat higher results in the total future population, depends upon a fixed birth rate in conjunction with a decreasing death rate.

Natural causes, or the excess of births over deaths, contributed one-fourth of the total increase in the population of Chicago during the 60 years, 1850 to 1910.

A death rate of 15 per 1,000 of Chicago's population for the decade 1910 to 1920 is low. It is probable, in view of the world-wide downward tendency of the birth rate, that the rate for Chicago will drop steadily during the years for which an estimate of population has been made. While no sufficiently complete system of registration of births has heretofore been in operation in Chicago to permit of the determination of a birth rate for the city, it is evident from the birth rates determined by cities and states having adequate registration of births that the rate for Chicago in 1913 must have been about 26.5.

The resultant rates used in determining the natural

TABLE CDLVIII. ESTIMATED INCREASE IN FUTURE POPULATION OF CHICAGO, CLASSIFIED BY SOURCES OF INCREASE
1910-1950

Decade	Total Estimated Population at Close of Decade	Estimated Increase in Total Population		Estimated Increase in Native-Born				Estimated Increase in Foreign-Born Due to Immigration and Migration
						Due to Migration		
		Total Estimated Increase	Per Cent of Increase	Total Estimated Increase	Due to Natural Causes	From Other States	From Other Parts of Illinois	
1	2	3	4	5	6	7	8	9
1. Decreasing Birth Rate and Decreasing Death Rate								
1910–1920	2,715,608	530,325	24.27	355,325	240,325	30,000	85,000	175,000
1920–1930	3,246,340	530,732	19.54	380,732	270,732	30,000	80,000	150,000
1930–1940	3,766,909	520,569	16.04	395,569	290,569	30,000	75,000	125,000
1940–1950	4,267,803	500,894	13.30	400,894	300,894	30,000	70,000	100,000
Totals	....	2,082,520	95.30	1,532,520	1,102,520	120,000	310,000	550,000
2. Fixed Birth Rate and Decreasing Death Rate								
1910–1920	2,728,434	543,151	24.85	368,151	253,151	30,000	85,000	175,000
1920–1930	3,307,487	579,053	21.22	429,053	319,053	30,000	80,000	150,000
1930–1940	3,927,076	619,589	18.73	494,589	389,589	30,000	75,000	125,000
1940–1950	4,594,418	667,342	16.99	567,342	467,342	30,000	70,000	100,000
Totals	....	2,409,135	110.24	1,859,135	1,429,135	120,000	310,000	550,000

TABLE CDLIX. DECREASING BIRTH RATE AND DECREASING DEATH RATE PER 1,000 OF POPULATION

Decade	Birth Rate	Death Rate	Resultant
1	2	3	4
1910–1920	24.80	14.97	9.83
1920–1930	23.80	14.70	9.10
1930–1940	22.80	14.50	8.30
1940–1950	21.80	14.30	7.50

TABLE CDLX. FIXED BIRTH RATE AND DECREASING DEATH RATE PER 1,000 OF POPULATION

Decade	Birth Rate	Death Rate	Resultant
1	2	3	4
1910–1920	25.30	14.97	10.33
1920–1930	25.30	14.70	10.60
1930–1940	25.30	14.50	10.80
1940–1950	25.30	14.30	11.00

increase in population, as shown in the upper part of table CDLVIII, are given in table CDLIX, and the resultant rates used in determining the natural increase in population, as shown in the lower part of table CDLVIII, are given in table CDLX.

CHANGES IN POPULATION OF CHICAGO, NEW YORK, BOSTON AND PHILADELPHIA, AND OF THEIR ADJACENT TERRITORY

701.25 Increases in Population of Chicago and of its Industrial Zone (Embracing the Counties within a Radius of 50 Miles): The numerical and percentage changes in the population of Chicago and of its outlying industrial zone, embracing the counties within a radius of 50 miles of the city, are shown, by decades, from 1860 to 1910 in table CDLXI. A comparative statement, covering the same period, of the changes in population of the Illinois and Indiana counties within this zone is presented as table CDLXII. A graphic presentation of these changes is given in fig. 703.

The marked decline, after 1890, in the decennial rates of increase in the total population, was due to the fact that the rate of increase of the city, which contributed so largely to the whole, was itself decreasing rapidly, while the rate of increase in the population of the zone outside the city, though advancing, was not sufficient to prevent the general decline in the rate.

The relatively low numerical increase from 1880 to 1890 in the zone outside the city was largely due to annexation by the city. Notwithstanding this, the rural districts alone contributed 5.30 per cent of the total net gain added to the population of the district by the zone outside the city during the 50 years.

TABLE CDLXI. INCREASES IN POPULATION OF CHICAGO AND OF THE INDUSTRIAL ZONE OUTSIDE OF CHICAGO
1860–1910

Decade	Increase in Total Population of Zone		Increase in the Population of the City of Chicago		Increase in the Population of the Industrial Zone Outside of the City of Chicago					
							Increase in Cities and Villages		Increase in Rural Districts	
	Total Increase	Per Cent of Increase	Total Increase	Per Cent of Increase	Total Increase	Per Cent of Increase in Total Population	Total Increase	Per Cent of Total Increase Outside of the City of Chicago	Total Increase	Per Cent of Total Increase Outside of the City of Chicago
1	2	3	4	5	6	7	8	9	10	11
1860–1870	257,937	75.7	189,717	173.6	68,220	26.45	18,166	26.63	50,054	73.37
1870–1880	290,852	48.6	204,208	68.3	86,644	29.79	85,675	98.88	969	1.12
1880–1890	640,720	72.0	596,665	118.6	44,055	6.88	70,135	159.20	—26,080*	—59.20
1890–1900	722,825	47.2	598,725	54.4	124,100	17.17	123,240	99.31	860	0.69
1900–1910	674,397	29.9	486,708	28.7	187,689	27.83	186,428	99.33	1,261	0.67
Totals	2,586,731	759.4	2,076,023	1900.1	510,708	19.74	483,644	94.70	27,064	5.30

* Minus sign (—) denotes decrease.

TABLE CDLXII. STATISTICS OF POPULATION OF COUNTIES IN ILLINOIS AND INDIANA WITHIN A RADIUS OF 50 MILES OF CHICAGO AS SHOWN BY THE UNITED STATES CENSUS. DECADES 1860 TO 1910, INCLUSIVE

United States Census, Decade Ending 1860

County	Area Sq. Miles	Population of County							Rural Population of County					Population of Cities and Villages					Population per Square Mile				
		Total	Per Cent in Rural Communities	Per Cent in Cities and Villages	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease			
					Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860	
					No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Cook ..... Ill.	993	144,951	23.2	76.8	101,569	234.1			34,661	21,239	158.2	.....	.....	110,293	80,330	268.1			146.0	102.7	231.1	.....	.....
Du Page . "	347	11,701	95.6	4.4	5,411	58.2			14,056	4,766	51.3		.....	645	645				42.4	15.6	58.2	.....	.....
Grundy ... "	432	10,379	79.7	20.3	7,356	243.3			8,274	5,251	173.7	...	....	2,105	2,105	....	....		24.0	17.0	213.3	.....	.....
Kane ... "	540	30,062	53.8	46.2	13,359	80.0			16,169	−534	−3.2		...	13,893	13,893	....		.....	55.7	24.8	80.0	.....	.....
Kankakee .. "	692	15,412	100.0	00.0	15,412	......	.....		15,412	15,412	0.0		...	....	....	....			22.3	22.3	.....	.....	.....
Kendall .... "	324	13,071	100.0	00.0	5,341	69.1			13,074	5,314	69.1		....			...		.....	40.4	16.5	69.1	.....	.....
Lake ..... "	463	18,257	81.2	18.8	4,031	28.3			14,824	598	4.2		...	3,433	3,433	...		.....	39.4	8.7	28.3	.....	.....
McHenry . "	609	22,089	88.9	11.1	7,111	47.5			19,643	4,665	31.1		...	2,446	2,446			.....	36.3	11.7	47.5	.....	.....
Will ...... "	835	29,321	75.8	21.2	12,618	75.5			22,219	8,175	58.2		.	7,102	4,443	167.1	...	...	35.1	15.1	75.5	.....	.....
Lake ... Ind.	465	9,145	100.0	00.0	5,151	129.1			9,145	5,154	129.1			....	....	....	....	.....	19.7	11.1	129.1	.....	.....
Laporte . "	563	22,919	63.6	36.4	10,771	88.7		.	14,571	5,249	56.3			8,348	5,525	195.7	.....	.....	40.7	21.6	88.7	.....	.....
Porter . "	418	10,313	83.5	16.5	5,079	97.0		.	8,615	3,003	82.8		...	1,698	1,176	225.3	.....	.	24.7	12.2	97.0	.....	.....
Totals, Ill	5,235	298,249	53.1	46.9	172,211	136.6			158,332	64,916	69.5	.	...	139,917	107,295	328.9	...	.	57.0	32.9	136.6	...	.....
Totals, Ind	1,446	42,377	76.3	23.7	21,007	98.3			32,331	14,306	79.4	...	......	10,016	6,701	200.3	...		29.3	14.5	98.3	.....	.....
Grand totals	6,681	340,626	56.0	44.0	193,218	131.1			190,663	79,272	71.2		...	149,963	113,996	316.9			51.0	28.9	131.1	.....	.....
United States Census, Decade Ending 1870																							
Cook Ill	993	349,966	14.4	85.6	205,012	111.4	205,012	111.4	50,524	15,863	45.8	15,863	45.8	299,442	189,149	171.5	189,149	171.5	352.4	206.4	141.4	206.4	141.4
Du Page .. "	347	16,685	81.8	18.2	1,984	13.5	1,984	13.5	13,645	−411	−3.0	−411	−3.0	3,040	2,395	371.3	2,395	371.3	48.1	5.7	13.5	5.7	13.5
Grundy .. "	432	14,938	72.7	27.3	4,559	43.9	4,559	43.9	10,860	2,586	31.3	2,586	31.3	4,078	1,973	93.7	1,973	93.7	34.6	10.6	43.9	10.6	43.9
Kane .... "	540	39,091	57.5	42.5	9,029	30.0	9,029	30.0	22,488	6,319	39.1	6,319	39.1	16,603	2,710	19.5	2,710	19.5	72.4	16.7	30.0	16.7	30.0
Kankakee .. "	692	24,352	100.0	00.0	8,940	58.0	8,940	58.0	24,352	8,940	58.0	8,940	58.0	....	....	......	....	......	35.2	12.9	58.0	12.9	58.0
Kendall .... "	324	12,399	100.0	00.0	−675*	−5.2	−675	−5.2	12,399	−675	−5.2	−675	−5.2	....	....	......	....	......	38.3	−2.1	−5.2	−2.1	−5.2
Lake .... "	463	21,014	78.6	21.4	2,757	15.1	2,757	15.1	16,507	1,683	11.4	1,683	11.4	4,507	1,074	31.3	1,074	31.3	45.4	6.0	15.1	6.0	15.1
McHenry .. "	609	23,762	83.1	16.9	1,673	7.6	1,673	7.6	19,741	98	0.5	98	0.5	4,021	1,575	64.4	1,575	61.4	39.0	2.7	7.6	2.7	7.6
Will .... "	835	43,013	71.7	28.3	13,692	46.7	13,692	46.7	30,829	8,610	38.8	8,610	38.8	12,184	5,082	71.6	5,082	71.6	51.5	16.4	46.7	16.4	46.7
Lake ...... Ind.	465	12,339	100.0	00.0	3,194	34.9	3,194	34.9	12,339	3,191	31.9	3,194	34.9	....	....	......	....	......	26.5	6.8	34.9	6.8	34.9
Laporte .. "	563	27,062	58.6	41.4	4,113	18.1	4,143	18.1	15,856	1,285	8.8	1,285	8.8	11,206	2,858	34.2	2,858	34.2	48.1	7.4	18.1	7.4	18.1
Porter ... "	418	13,942	80.2	19.8	3,629	35.3	3,629	35.3	11,177	2,562	29.7	2,562	29.7	2,765	1,067	62.8	1,067	62.8	33.4	8.7	35.3	8.7	35.3
Totals, Ill ...	5,235	545,220	36.9	63.1	246,971	82.8	246,971	82.8	201,315	43,013	27.2	43,013	27.2	343,875	203,958	145.8	203,958	145.8	101.1	47.1	82.8	47.1	82.8
Tntals, Ind ..	1,446	53,343	73.8	26.2	10,966	25.9	19,066	25.9	39,372	7,041	21.8	7,041	21.8	13,971	3,925	39.1	3,925	39.1	36.9	7.6	25.9	7.6	25.9
Grand totals.	6,681	598,563	40.2	59.8	257,937	75.7	257,937	75.7	240,717	50,054	26.3	50,054	26.3	357,846	207,883	138.6	207,883	138.6	89.6	38.6	75.7	38.6	75.7
United States Census, Decade Ending 1880																							
Cook ..... Ill.	993	607,524	12.4	87.6	257,558	73.6	462,570	319.1	75,322	24,798	49.1	40,661	117.3	532,202	232,760	77.7	421,909	382.5	611.8	259.4	73.6	465.8	319.1
Du Page .. "	347	19,161	61.9	38.1	2,476	14.8	1,460	30.3	11,862	−1,783	−13.1	−2,194	−15.8	7,299	4,259	140.1	6,654	1,031.6	55.2	7.1	14.8	12.8	30.3
Grundy ... "	432	16,732	70.3	29.7	1,791	12.0	6,353	61.2	11,766	906	8.3	3,492	42.2	4,966	888	21.8	2,861	135.9	38.8	4.2	12.0	14.8	61.2
Kane ..... "	540	44,939	35.6	64.4	5,848	15.0	14,877	49.5	16,009	−6,479	−28.8	−160	−0.1	28,930	12,327	74.2	15,037	108.2	83.2	10.8	15.0	27.5	49.5
Kankakee .. "	602	25,017	65.3	34.7	695	2.9	9,635	62.5	16,350	−8,002	−32.9	938	6.1	8,697	8,697	......	8,697	....	36.2	1.0	2.9	13.9	62.5
Kendall .... "	324	13,083	73.6	26.4	684	5.5	9	00.0	9,623	−2,776	22.4	−3,451	−26.4	3,460	3,460	......	3,460	....	40.4	2.1	5.5	00.0	00.0
Lake .... "	463	21,296	65.4	34.6	282	1.3	3,039	16.6	13,926	−2,581	−15.6	−898	−6.1	7,370	2,863	63.3	3,937	114.7	46.0	0.6	1.3	6.6	16.6
McHenry .. "	609	24,908	71.4	28.6	1,146	4.8	2,819	12.8	17,785	−1,956	−9.9	−1,858	−9.5	7,123	3,102	77.1	4,677	191.2	40.9	1.9	4.8	4.6	12.8
Will .. .... "	835	53,422	51.6	45.4	10,409	24.2	21,101	82.2	29,172	−1,657	−5.3	6,953	31.3	24,250	12,066	99.0	17,148	241.4	64.0	12.5	24.2	28.9	82.2
Lake ..... Ind.	465	15,091	76.3	23.7	2,752	22.3	5,916	65.0	11,511	−828	−6.7	2,360	25.9	3,580	3,580	......	3,580	....	32.5	6.0	22.3	12.8	65.0
Laporte .. "	563	30,985	54.2	45.8	3,923	14.5	8,066	35.2	16,797	941	5.9	2,226	15.3	14,188	2,082	26.6	5,840	69.9	55.0	6.9	14.5	14.3	35.2
Porter ... "	418	17,227	67.1	32.9	3,285	23.6	6,914	67.0	11,563	386	3.5	2,948	34.2	5,661	2,899	104.8	3,966	233.6	41.2	7.8	23.6	16.5	67.0
Totals, Ill	5,235	826,112	21.4	75.6	280,802	51.5	527,863	177.0	201,815	470	0.2	43,483	27.5	624,297	280,422	81.5	481,380	316.2	157.8	53.7	51.5	100.8	177.0
Totals, Ind ..	1,446	63,303	63.0	37.0	9,960	18.7	20,926	49.4	39,871	499	1.3	7,510	23.3	23,432	9,461	67.7	13,386	133.2	43.8	6.9	18.7	14.5	49.4
Grand totals.	6,681	889,415	27.2	72.8	290,852	48.6	548,789	161.1	241,686	969	0.4	51,023	26.8	647,729	289,883	81.0	497,766	331.9	133.1	43.5	48.6	82.1	161.1

* Minus sign (—) denotes decrease.

TABLE CDLXII (Continued). STATISTICS OF POPULATION OF COUNTIES IN ILLINOIS AND INDIANA WITHIN A RADIUS OF 50 MILES OF CHICAGO AS SHOWN BY THE UNITED STATES CENSUS. DECADES 1860 TO 1910. INCLUSIVE

County	Area Sq. Miles	Population of County: Total	Population of County: Per Cent in Rural Communities	Population of County: Per Cent in Cities and Villages	Population of County: Increase or Decrease Over Preceding Census No.	Population of County: Increase or Decrease Over Preceding Census Per Cent	Population of County: Increase or Decrease Over Census 1860 No.	Population of County: Increase or Decrease Over Census 1860 Per Cent	Rural Population of County: Total	Rural Population of County: Increase or Decrease Over Preceding Census No.	Rural Population of County: Increase or Decrease Over Preceding Census Per Cent	Rural Population of County: Increase or Decrease Over Census 1860 No.	Rural Population of County: Increase or Decrease Over Census 1860 Per Cent	Population of Cities and Villages: Total	Population of Cities and Villages: Increase or Decrease Over Preceding Census No.	Population of Cities and Villages: Increase or Decrease Over Preceding Census Per Cent	Population of Cities and Villages: Increase or Decrease Over Census 1860 No.	Population of Cities and Villages: Increase or Decrease Over Census 1860 Per Cent	Population per Square Mile: Total	Population per Square Mile: Increase or Decrease Over Preceding Census No.	Population per Square Mile: Increase or Decrease Over Preceding Census Per Cent	Population per Square Mile: Increase or Decrease Over Census 1860 No.	Population per Square Mile: Increase or Decrease Over Census 1860 Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
United States Census. Decade Ending 1890																							
Cook ... Ill.	993	1,191,922	4.8	95.2	584,398	96.2	1,046,968	722.3	57.140	—18.182	—24.1	22,479	64.9	1.134.782	602.580	113.2	1.024.489	928.9	1.200.3	588.5	96.2	1,054.3	722.3
Du Page. "	347	22.551	50.5	49.5	3.390	17.7	7,850	53.4	11,382	—480	......	—2,674	—19.0	11,169	3.870	53.0	10,524	1,631.6	65.0	9.8	17.7	22.6	53.4
Grundy.. "	432	21,024	52.3	47.7	4.292	25.7	10.645	102.6	10.997	—769	—6.5	2.723	32.9	10.027	5.061	101.9	7.922	376.3	48.7	9.9	25.7	24.7	102.6
Kane. . "	540	65.061	23.7	76.3	20,122	44.8	34.999	116.4	15.418	—591	—3.7	—751	—4.6	49.643	20,713	71.6	35.750	257.3	120.5	37.3	44.8	64.8	116.4
Kankakee "	692	28,732	52.8	47.2	3,685	14.7	13,320	86.4	15.162	—1.188	—7.3	—250	—1.6	13.570	4.873	56.0	13.570	......	41.5	5.3	14.7	19.2	86.4
Kendall.. "	324	12.106	71.6	28.4	—977*	—7.5	—968	—7.5	8.663	—960	—10.0	—4,411	—33.7	3,443	—17	—0.5	3,443	......	37.4	3.0	—7.5	3.0	—7.5
Lake..... "	463	24,235	57.9	42.1	2.939	13.8	5.978	32.7	14,020	94	0.7	—804	—5.4	10.215	2.845	38.6	6.782	197.5	52.3	6.3	13.8	12.9	32.7
McHenry "	609	26.114	68.4	31.6	1,206	4.8	4,025	18.2	17,856	71	0.4	—1,787	—9.1	8.258	1,135	15.9	5.812	237.6	42.9	2.0	4.8	6.6	18.2
Will ... "	835	62,007	41.1	58.9	8.585	16.1	32.686	111.5	25,488	—3.684	—12.6	3,269	14.7	36.519	12.269	50.6	29.417	414.2	74.3	10.3	16.1	39.2	111.5
Lake... Ind.	465	23,886	50.7	49.3	8.795	58.3	14.741	161.2	12,117	606	5.3	2.972	32.5	11.769	8.189	228.7	11.769	.....	51.4	18.9	58.3	31.7	161.2
Laporte "	563	34,445	46.5	53.5	3.460	11.5	11.526	50.3	16,021	—776	—4.6	1.450	10.0	18.424	4.236	29.8	10.076	120.7	61.2	6.2	11.5	20.5	50.3
Porter.. "	418	18,052	62.8	37.2	825	4.8	7.739	75.0	11.342	—221	—1.9	2.727	31.7	6.710	1.046	18.5	5.012	295.2	43.2	2.0	4.8	18.5	75.0
Totals, Ill.	5,235	1,453.752	12.1	87.9	627,640	76.0	1,155.503	387.4	176.126	—25.689	—12.7	17.794	11.2	1.277.626	653,329	104.7	1.137.709	813.1	277.7	119.9	76.0	220.7	387.4
Totals. Ind	1.446	76.383	51.7	48.3	13.080	20.7	34,006	80.2	39.480	—391	—1.0	7.149	22.1	36.903	13.471	57.5	26,857	267.3	52.8	9.0	20.7	23.5	80.2
Grand totals	6,681	1.530.135	14.1	85.9	640.720	72.0	1,189,509	349.2	215,606	—26,080	—10.8	24,943	13.1	1.314,529	666,800	102.9	1,164.566	776.6	229.0	95.9	72.0	178.0	349.2
United States Census. Decade Ending 1900																							
Cook.... Ill.	993	1,838,735	2.8	97.2	646,813	51.3	1,693.781	1168.5	51,398	—5,742	—10.0	16.737	48.3	1.787.337	652.555	57.5	1,677.044	1,520.5	1,851.7	651.4	54.3	1,705.7	1168.5
Du Page. "	347	28.196	42.9	57.1	5,645	25.0	13,495	91.8	12,097	715	6.3	—1.959	—13.9	16,099	4,930	44.1	15.454	2,395.9	81.2	16.2	25.0	38.8	91.8
Grundy.. "	432	24.136	42.5	57.5	3.112	14.8	13.757	132.5	10.252	—745	—6.8	1.978	23.9	13.884	3.857	38.5	11,779	559.6	55.9	7.2	14.8	31.9	132.5
Kane.... "	540	78.792	21.3	78.7	13.731	21.1	48,730	162.1	16.796	1,378	8.9	627	3.9	61.996	12.353	24.9	48.103	346.2	145.9	25.4	21.1	90.2	162.1
Kankakee "	692	37.154	39.4	60.6	8.422	29.3	21.742	141.1	14,644	—518	—3.4	—768	—5.0	22.510	8.940	65.9	22.510	......	53.7	12.2	29.3	31.4	141.1
Kendall.. "	324	11.467	65.4	34.6	—639	—5.3	—1.607	—12.3	7,496	—1,167	—13.5	—5.578	—42.6	3.971	528	15.3	3.971	......	35.4	—2.0	—5.3	—5.0	—12.3
Lake.... "	463	34.504	40.7	59.3	10.269	42.4	16,247	89.0	14.036	16	0.1	—788	—5.3	20,468	10.253	100.4	17,035	496.2	74.5	22.2	42.4	35.1	89.0
McHenry "	609	29.759	57.2	42.8	3.645	14.0	7,670	34.7	17.020	—836	—4.7	—2.623	—13.4	12.739	4.481	54.3	10,293	420.8	48.9	6.0	14.0	12.6	31.7
Will ... "	835	74,764	43.3	56.7	12,757	20.6	45.443	151.9	32.338	6.850	26.9	10.119	45.5	42.426	5,907	16.2	35,324	497.4	89.5	15.2	20.6	54.4	154.9
Lake... Ind.	465	37.892	34.6	65.4	14,006	58.6	28.747	314.4	13,121	1.004	8.3	3.976	43.5	24.771	13,002	110.5	24.771	......	81.5	30.1	58.6	61.8	314.4
Laporte. "	563	38,386	41.6	58.4	3.941	11.4	15,467	67.5	15.955	—66	—0.4	1.384	9.5	22.431	4.007	21.7	14.083	168.7	68.2	7.0	11.4	27.5	67.5
Porter "	418	19.175	59.0	41.0	1.123	6.2	8,862	85.4	11.313	—29	—0.3	2,698	31.3	7.862	1.152	17.2	6.164	363.0	45.9	2.7	6.2	21.2	85.4
Totals, Ill.	5,235	2.157,507	8.2	91.8	703,755	48.4	1.859,258	623.4	176,077	—49	—00.0	17.745	11.2	1,981,430	703.804	55.1	1.841,513	1.316.1	412.1	134.4	48.4	355.1	623.4
Totals. Ind.	1.446	95.453	42.3	57.7	19.070	25.0	53,076	125.2	40.389	909	2.3	8.058	24.9	55.064	18.161	49.2	45.018	448.1	66.0	13.2	25.0	38.7	125.2
Grand totals	6,681	2,252.960	9.6	90.4	722,825	47.2	1,912.334	561.4	216,466	860	0.4	25,803	13.5	2,036,494	721,965	54.9	1.886,531	1,258.0	337.2	108.2	47.2	286.2	561.4
United States Census. Decade Ending 1910																							
Cook .. Ill.	993	2.405,233	2.1	97.9	566,498	30.8	2.260.279	1559.3	51,671	273	0.5	17.010	49.1	2.353.562	566,225	31.7	2,243.269	2,033.9	2.422.2	570.5	30.8	2,276.2	1559.3
Du Page "	347	33,432	36.8	63.2	5,236	18.6	18.731	127.4	12,307	210	1.7	—1.749	—12.4	21,125	5.026	31.2	20,480	3,175.2	96.3	15.1	18.6	53.9	127.4
Grundy.. "	432	24.162	36.8	63.2	26	0.1	13.783	132.8	8,882	—1.370	13.4	608	7.3	15.280	1,396	10.1	13,175	625.9	55.9	0.0	0.1	31.9	132.8
Kane.... "	540	91.862	19.3	80.7	13.070	16.6	61,800	205.6	17,769	973	5.8	1,600	10.0	74,093	12,097	19.5	60.200	433.3	170.1	24.2	16.6	114.4	205.6
Kankakee "	692	40,752	41.0	59.0	3.598	9.7	25,340	164.4	16,711	2.067	14.1	1.299	8.4	24,041	1,531	6.8	24,041	......	58.9	5.2	9.7	36.6	164.4
Kendall.. "	324	10,777	64.8	35.2	—690	—6.0	—2.297	—17.6	6,980	—516	—6.9	—6.094	—46.6	3,797	—174	—4.4	3.797	......	33.3	—2.1	—6.0	—7.1	—17.6
Lake.... "	463	55.058	27.1	72.9	20.554	59.6	36,801	201.6	14.932	896	6.4	108	0.7	40.126	19.658	96.0	36.693	1,068.8	118.9	44.4	59.6	79.5	201.6
McHenry "	609	32.509	50.3	49.7	2.750	9.2	10.420	47.2	16.345	—675	—4.0	—3.298	—16.8	16,164	3.425	26.9	13.718	560.8	53.4	4.5	9.2	17.1	47.2
Will .. "	835	84.371	41.4	58.6	9,607	12.8	55,050	187.7	34,945	2.607	8.1	12.726	57.3	49.426	7.000	16.5	42,324	595.9	101.0	11.5	12.8	65.9	187.7
Lake Ind	465	82,864	12.8	87.2	44.972	118.7	73.719	806.1	10,635	—2,486	—18.9	1,490	16.3	72,229	47,458	190.8	72.229	......	178.2	96.7	118.7	158.5	806.1
Laporte.. "	563	45.797	34.4	65.6	7.411	19.3	22.878	99.8	15.742	—113	—0.7	1,171	8.0	30.055	7.624	34.0	21.707	261.2	81.3	13.1	19.3	40.6	99.8
Porter. . "	418	20,540	52.6	47.4	1.365	7.1	10.227	99.2	10.808	—505	—4.4	2.193	25.4	9.732	1.870	23.8	8.034	473.1	49.1	3.2	7.1	21.4	99.2
Totals. Ill	5.235	2.778.156	6.5	93.5	620.649	28.8	2.479,907	831.5	180.542	4.465	2.5	22.210	14.0	2.597.614	616,184	31.1	2,457,697	1.756.5	530.7	118.6	28.8	473.7	831.5
Totals. Ind	1.446	149.204	24.9	75.1	53,748	56.3	106.824	252.1	37.185	—3.204	—7.9	4,854	15.0	112.016	56,952	103.4	101,970	1,015.0	103.2	37.2	56.3	73.9	252.1
Grand totals	6.681	2,927.357	7.4	92.6	674.397	29.9	2,586,731	759.4	217,727	1.261	0.6	27.061	14.2	2.709.630	673,136	33.1	2.559.667	1,708.9	438.2	101.0	29.9	387.2	759.4

* Minus sign (—) denotes decrease.

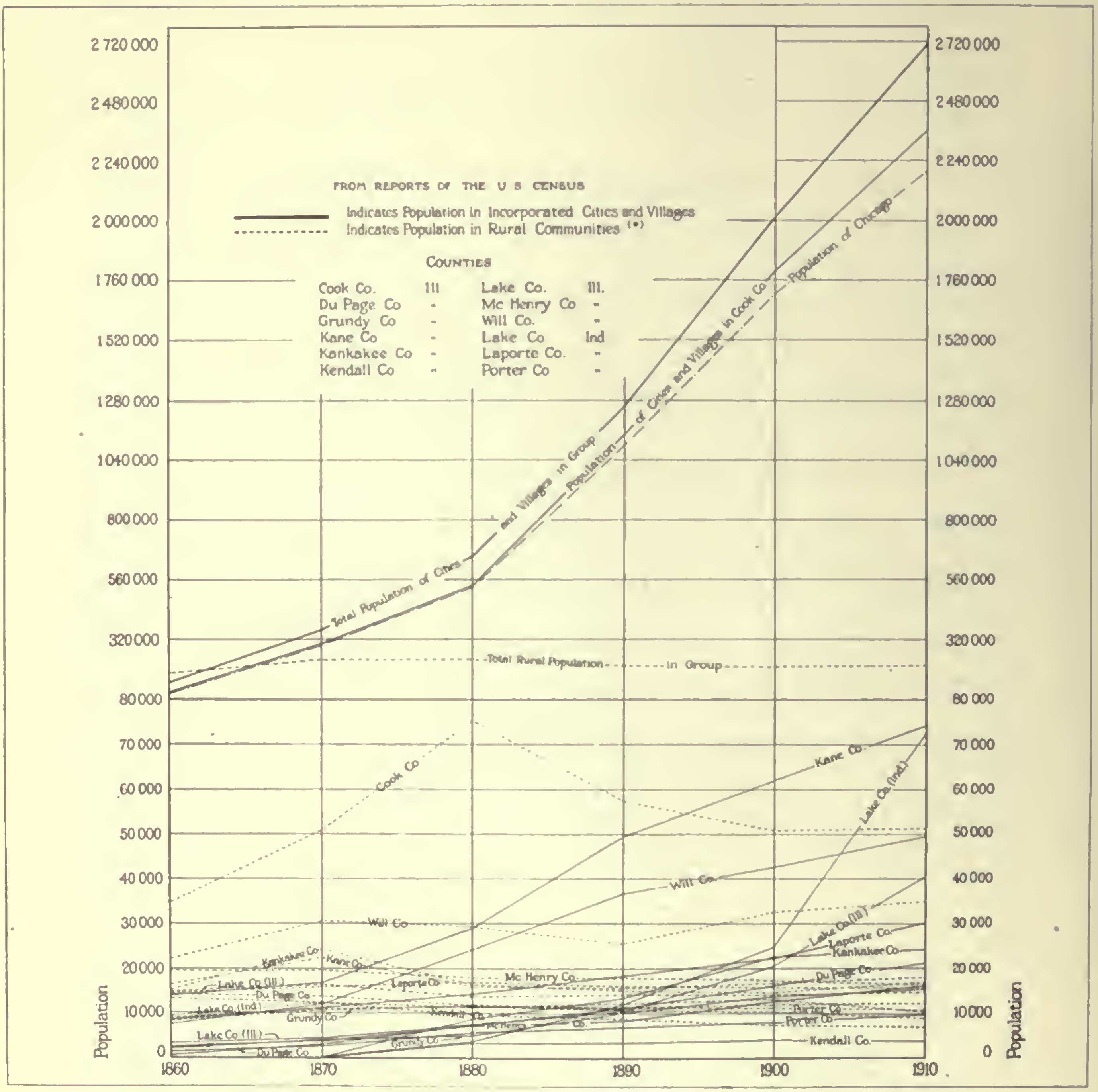

FIG. 703. CHANGES IN URBAN AND RURAL POPULATION OF ILLINOIS AND INDIANA COUNTIES WITHIN 50 MILES OF CHICAGO, 1860-1910

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* Includes all population outside of incorporated cities and villages.

701.26 Increases in the Population of New York and of its Industrial Zone (Embracing the Counties within a Radius of 50 Miles): The numerical and percentage changes in the population of New York and of its outlying industrial zone, embracing the counties within a radius of 50 miles of the city, are shown by decades from 1860 to 1910 in table CDLXIII. The statistical record of population changes in this zone is given in table CDLXIV. A graphic presentation of the changes in the population and area of the city of New York alone is shown as fig. 704.

A study of the statistics here presented shows that the decennial percentage increases advance throughout almost the whole period, being respectively 28.3, 26.2, 29.8, 34.4 and 37.8 per cent. Aside from the large artificial increase from 1890 to 1900, due to the annexation of additional area, the city itself also made substantial gains in its decennial percentage increases of population, though these were offset somewhat in the general result by declining increases in the zone outside the city. The latter was, however, affected by the inclusion within the corporate limits of the city of some of its area.

701.27 Increases in the Population of Boston and of its Industrial Zone (Embracing the Counties within a Radius of 50 Miles): The numerical and percentage changes in the population of Boston and of its outlying industrial zone, embracing the counties within a radius of 50 miles of the city, are shown by decades from 1860 to 1910 in table CDLXV. The statistical record of population changes in this zone is given in table CDLXVI. A graphic presentation of the changes in population and area of the city of Boston alone is shown as fig. 705.

A study of the statistics here presented shows a decline after the decade 1880 to 1890 in the decennial increases in the total population, due chiefly to the fact that the rate of increase in the population of the city lessened while that in the population of the zone outside the city remained practically uniform throughout the whole period.

The increases in the zone outside the city show a remarkable growth in three of the decades for the cities and villages, with actual decreases in the population of the rural districts, the latter showing a net decrease of 2.03 per cent for the 50 years.

The numerical increases in the total population are especially noteworthy, varying from 240,281 in the earliest decade to 611,731 in the latest decade.

701.28 Increases in the Population of Philadelphia and of its Industrial Zone (Embracing the Counties within a Radius of 50 Miles): The numerical and percentage changes in the population of Philadelphia and of its outlying industrial zone are embracing the counties within a radius of 50 miles of the city, are shown by decades from 1860 to 1910 in table CDLXVII. The statistical record of population changes in this zone is given in table CDLXXIII. A graphic presentation of the changes in population and area of the city of Philadelphia alone is shown as fig. 706.

A study of the statistics here presented shows that the decennial percentage increases in the total population are remarkably even, ranging from 16.8 per cent from 1860 to 1870, to 19.6 per cent from 1900 to 1910. From the decade 1870 to 1880 the city's rate of increase declined, while the increases of the zone outside of the city showed an upward tendency.

The numerical increases in the total population advanced from 255,464 in the first decade to 588,042 in the latest decade.

701.29 Comparative Increases in the Population of Cities and Villages Lying within Each Industrial Zone, Exclusive of the Largest City of Each Zone: The numerical and percentage changes in population of cities and villages in the industrial zone of each of the four cities under consideration, exclusive of the population of the city itself, are shown, by decades from 1860 to 1910, in table CDLXVIII.

In any consideration of these figures, it must be borne in mind that they are affected by the annexations made from time to time by the chief city of the zone. For illustration of this fact, it is only necessary to compare the figures of New York and Boston. The latter shows a greater total increase for the whole period than New York, but the period from 1890 to 1900 witnessed an actual loss in the territory outside of New York through the annexation of large areas. With this allowance, the order in total increase for the five decades would be New York, Boston, Philadelphia and Chicago.

From 1860 to 1910 the total increase of the four cities was 5,175,823. Of this amount New York contributed 34.98 per cent, Boston 35.81 per cent, and

TABLE CDLXIII. INCREASES IN THE POPULATION OF NEW YORK AND OF THE INDUSTRIAL ZONE OUTSIDE OF NEW YORK 1860-1910

Decade	Increase in Total Population of Zone		Increase in the Population of the City of New York		Increase in the Population of the Industrial Zone Outside of the City of New York					
					Total Increase	Per Cent of Increase in Total Population	Increase in Cities and Villages		Increase in Rural Districts	
	Total Increase	Per Cent of Increase	Total Increase	Per Cent of Increase			Total Increase	Per Cent of Total Increase Outside of the City of New York	Total Increase	Per Cent of Total Increase Outside of the City of New York
1	2	3	4	5	6	7	8	9	10	11
1860–1870	563,678	28.3	128,623	15.8	435,055	77.18	418,007	96.08	17,048	3.92
1870–1880	668,909	26.2	264,007	28.0	404,902	60.53	434,463	107.30	—29,561	—7.30
1880–1890	961,152	29.8	309,002	25.6	652,150	67.85	627,404	96.21	24,746	3.79
1890–1900	1,440,227	34.4	1,921,901	126.8	—481,674*	—33.44	—393,162	—81.62	—88,512	18.38
1900–1910	2,124,520	37.8	1,329,681	38.7	794,839	37.41	723,523	91.03	71,316	8.97
Totals	5,758,486	289.3	3,953,214	485.9	1,805,272	31.35	1,810,235	100.27	—4,963	—0.27

* Minus sign (—) denotes decrease.

TABLE CDLXIV. STATISTICS OF POPULATION OF COUNTIES IN THE STATES OF CONNECTICUT, NEW JERSEY AND NEW YORK WITHIN 50 MILES OF NEW YORK CITY, AS SHOWN BY THE UNITED STATES CENSUS, DECADES ENDING 1860 TO 1910, INCLUSIVE

County	Area Sq. Miles	Population of County							Rural Population of County					Population in Cities and Villages					Population per Square Mile				
		Total	Per Cent in Rural Communities	Per Cent in Urban Communities	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease			
					Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860	
					No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
United States Census, Decade Ending 1860																							
Fairfield, Conn.	631	77,476	84.4	15.6	17,701	29.6	....	....	65,400	....	....	....	....	12,076	....	....	....	....	122.8	....	....	....	....
Bergen . . . N. J.	237	21,618	100.0		6,893	46.8	....	....	21,618	....	....	....	....	....	....	....	....	....	91.2	....	....	....	....
Essex . . . . "	127	98,877	18.3	81.7	24,927	33.7	....	....	18,059	....	....	....	....	80,818	....	....	....	....	778.5	....	....	....	....
Hudson . . "	43	62,717	23.4	76.6	40,895	187.4	....	....	14,658	....	....	....	....	48,059	....	....	....	....	1,158.5	....	....	....	....
Hunterdon "	437	33,654	88.5	11.5	4,664	16.1	....	....	29,781	....	....	....	....	3,873	....	....	....	....	77.0	....	....	....	....
Mercer . . . "	226	37,419	51.4	48.6	9,427	33.7	....	....	19,221	....	....	....	....	18,198	....	....	....	....	165.6	....	....	....	....
Middlesex. "	312	34,812	61.1	38.9	6,177	21.6	....	....	21,254	....	....	....	....	13,558	....	....	....	....	111.6	....	....	....	....
Monmouth "	479	39,346	100.0	..	9,033	29.8	....	....	39,346	....	....	....	....	....	....	....	....	....	82.1	....	....	....	....
Morris . . . "	475	34,677	100.0	..	4,519	15.0	....	....	34,677	....	....	....	....	....	....	....	....	....	73.0	....	....	....	....
Passaic . . . "	196	29,013	32.5	67.5	6,444	28.6	....	....	9,427	....	....	....	....	19,586	....	....	....	....	148.0	....	....	....	....
Somerset . . "	305	22,057	100.0	..	2,365	12.0	....	....	22,057	....	....	....	....	....	....	....	....	....	72.3	....	....	....	....
Sussex . . . "	529	23,846	92.4	7.6	857	3.7	....	....	22,022	....	....	....	....	1,824	....	....	....	....	45.1	....	....	....	....
Union . . . . "	103	27,780	21.1	78.9	27,780	....	....	....	5,859	....	....	....	....	21,921	....	....	....	....	269.7	....	....	....	....
Warren . . "	362	28,433	89.9	10.1	6,075	27.2	....	....	25,551	....	....	....	....	2,882	....	....	....	....	78.5	....	....	....	....
Kings . . . N. Y.	70	279,122	4.4	95.6	140,240	100.9	....	....	12,461	....	....	....	....	266,661	....	....	....	....	3,987.5	....	....	....	....
Nassau . . "	274	26,963	100.0	....	26,963	..	....	....	26,963	....	....	....	....	....	....	....	....	....	98.4	....	....	....	....
New York "	44	813,669	....	100.0	298,122	57.8	....	....		....	....	....	....	813,669	....	....	....	....	18,492.3	....	....	....	....
Orange . . "	834	63,812	81.1	18.9	6,667	11.7	....	....	51,724	....	....	....	....	12,088	....	....	....	....	76.5	....	....	....	....
Putnam . "	233	14,002	80.3	19.7	—136*	—1.0	....	....	11,232	....	....	....	....	2,770	....	....	....	....	60.1	....	....	....	....
Queens . . "	105	30,428	100.0	....	—6,405	—17.4	....	....	30,428	....	....	....	....	....	....	....	....	....	289.8	....	....	....	....
Richmond "	48	25,492	100.0	....	10,431	69.3	....	....	25,492	....	....	....	....	....	....	....	....	....	531.1	....	....	....	....
Rockland "	183	22,492	87.9	12.1	5,530	32.6	....	....	19,769	....	....	....	....	2,723	....	....	....	....	122.9	....	....	....	....
Suffolk . . "	924	43,275	100.0	....	6,353	17.2	....	....	43,275	....	....	....	....	....	....	....	....	....	46.8	....	....	....	....
Westchester"	467	99,497	79.2	20.8	41,234	70.8	....	....	78,785	....	....	....	....	20,712	....	....	....	....	213.1	....	....	....	....
Totals, Conn.	631	77,476	84.4	15.6	17,701	29.6	....	....	65,400	....	....	....	....	12,076	....	....	....	....	122.8	....	....	....	....
Totals, N. J.	3,831	494,249	57.4	42.6	150,056	43.6	....	....	283,530	....	....	....	....	210,719	....	....	....	....	129.0	....	....	....	....
Totals, N. Y.	3,182	1,418,752	21.2	78.8	528,999	59.5	....	....	300,129	....	....	....	....	1,118,623	....	....	....	....	445.9	....	....	....	....
Grand totals	7,644	1,990,477	32.6	67.4	696,756	53.9	....	....	649,059	....	....	....	....	1,341,418	....	....	....	....	260.3	....	....	....	....
United States Census, Decade Ending 1870																							
Fairfield, Conn.	631	95,276	73.2	26.8	17,800	23.0	17,800	23.0	69,765	4,365	6.7	4,365	6.7	25,511	13,435	111.3	13,435	111.3	151.0	28.2	23.0	28.2	23.0
Bergen . . N. J.	237	30,122	100.0	.....	8,504	39.3	8,501	39.3	30,122	8,504	39.3	8,504	39.3	....	....	....	....	....	127.1	35.9	39.3	35.9	39.5
Essex . . . . "	127	143,839	20.5	79.5	44,962	45.5	44,962	45.5	29,432	11,373	63.0	11,373	63.0	114,407	33,589	41.6	33,589	41.6	1,132.6	351.1	45.5	354.1	45.3
Hudson . . "	43	129,067	10.6	89.4	66,350	105.8	66,350	105.8	13,658	—1,000	—6.8	—1,000	—6.8	115,409	67,350	140.1	67,350	140.1	3,001.6	1,543.1	105.8	1,543.1	105.8
Hunterdon "	437	36,963	83.3	16.7	3,309	9.8	3,309	9.8	30,797	1,016	3.4	1,016	3.4	6,166	2,293	59.2	2,293	59.2	84.6	7.0	9.8	7.6	9.8
Mercer . . "	226	46,386	41.7	58.3	8,967	24.0	8,967	24.0	19,367	146	0.8	146	0.8	27,019	8,821	48.5	8,821	48.5	205.2	39.6	24.0	39.6	24.0
Middlesex "	312	45,029	60.2	39.8	10,217	29.3	10,217	29.3	27,110	5,856	27.6	5,856	27.6	17,919	4,361	32.2	4,361	32.2	144.3	32.7	29.3	32.7	29.3
Monmouth "	479	46,195	100.0	.....	6,849	17.4	6,849	17.4	46,195	6,849	17.4	6,849	17.4	....	....	....	....	....	96.4	14.3	17.4	14.3	17.4
Morris . . . "	475	43,137	100.0	.....	8,460	24.4	8,460	21.4	43,137	8,460	24.4	8,460	24.4	....	....	....	....	....	90.8	17.8	24.4	17.8	21.4
Passaic . . "	196	46,416	27.7	72.3	17,403	60.0	17,403	60.0	12,837	3,410	36.2	3,410	36.2	33,579	13,993	71.4	13,993	71.4	236.8	88.8	60.0	88.8	60.0
Somerset. "	305	23,510	83.8	16.2	1,453	6.6	1,453	6.6	19,709	—2,348	—10.6	—2,318	—10.6	3,801	3,801	....	3,801	....	77.1	4.8	6.6	4.8	6.6
Sussex . . . "	529	23,168	89.6	10.4	—678	—3.0	—678	—3.0	20,765	—1,257	—5.7	—1,257	—5.7	2,403	579	31.7	579	31.7	43.8	—1.3	—3.0	—1.3	—3.0
Union . . . "	103	41,859	23.1	76.9	14,079	50.7	14,079	50.7	9,674	3,815	65.1	3,815	65.1	32,185	10,264	46.8	10,264	46.8	406.4	136.7	50.7	136.7	50.7
Warren . . "	362	31,336	65.4	34.6	5,903	20.8	5,903	20.8	22,440	—3,111	—12.2	—3,111	—12.2	11,896	9,014	312.8	9,011	312.8	94.8	16.3	20.8	16.3	20.8
Kings . . . N. Y.	70	419,921	5.7	94.3	140,799	50.4	140,799	50.4	23,822	11,361	91.2	11,361	91.2	396,099	129,438	48.5	129,438	48.5	5,999.0	2,011.5	50.4	2,011.5	50.4
Nassau . . "	274	31,134	87.9	12.1	4,171	15.5	4,171	15.5	27,359	896	1.5	396	1.5	3,775	3,775	....	3,775	....	113.6	15.2	15.5	15.2	15.5
New York "	44	942,292	.....	100.0	128,623	15.8	128,623	15.8	....	....	....	....	....	942,292	128,623	15.8	128,623	15.8	21,415.5	2,923.2	15.8	2,923.2	15.8
Orange . . "	834	80,902	55.0	45.0	17,090	26.8	17,090	26.8	44,504	—7,220	—14.0	—7,220	—14.0	36,398	24,310	201.1	24,310	201.1	97.0	20.5	26.8	20.5	26.8
Putnam . "	233	15,420	80.0	20.0	1,418	10.1	1,418	10.1	12,334	1,102	9.8	1,102	9.8	3,086	316	11.4	316	11.4	66.2	6.1	10.1	6.1	10.1
Queens . . "	105	42,669	36.1	63.9	12,241	40.2	12,241	40.2	15,401	—15,027	—49.4	—15,027	—49.4	27,268	27,268	....	27,268	....	406.4	117.0	40.2	117.0	40.2
Richmond "	48	33,029	63.4	36.6	7,537	29.5	7,537	29.5	20,935	—4,557	—17.9	—4,557	—17.9	12,094	12,094	....	12,094	....	688.0	156.9	29.5	156.9	29.5
Rockland "	183	25,213	63.8	36.2	2,721	12.1	2,721	12.1	16,093	—3,676	—18.6	—3,676	—18.6	9,120	6,397	234.9	6,397	234.9	137.8	14.9	12.1	14.9	12.1
Suffolk . . "	924	46,924	65.8	34.2	3,649	8.4	3,649	8.4	30,880	—12,395	—28.6	—12,395	—28.6	16,044	16,044	....	16,044	....	50.8	4.0	8.4	4.0	8.4
Westchester"	467	131,348	60.7	39.3	31,851	32.0	31,851	32.0	79,771	986	1.3	986	1.3	51,577	30,865	149.0	30,865	149.0	281.3	68.2	32.0	68.2	32.0
Totals, Conn	631	95,276	73.2	26.8	17,800	23.0	17,800	23.0	69,765	4,365	6.7	4,365	6.7	25,511	13,135	111.3	13,435	111.3	151.0	28.2	23.0	28.2	23.0
Totals, N. J.	3,831	690,027	47.1	52.9	195,778	39.6	195,778	39.6	325,243	41,713	14.7	41,713	14.7	364,784	154,065	73.1	154,065	73.1	180.1	51.1	39.6	51.1	39.6
Totals, N. Y.	3,182	1,768,852	15.3	84.7	350,100	24.7	350,100	24.7	271,099	—29,030	—9.7	—29,030	—9.7	1,497,753	379,130	33.9	379,130	33.9	555.8	109.9	24.7	109.9	24.7
Grand totals	7,644	2,554,155	26.1	73.9	563,678	28.3	563,678	28.3	666,107	17,048	26.3	17,048	26.3	1,888,048	546,630	40.1	546,630	40.1	334.1	73.8	28.3	73.8	28.3

* Minus sign —) denotes decrease.

TABLE CDLXIV (Continued). STATISTICS OF POPULATION OF COUNTIES IN THE STATES OF CONNECTICUT, NEW JERSEY AND NEW YORK, WITHIN 50 MILES OF NEW YORK CITY, AS SHOWN BY THE UNITED STATES CENSUS, DECADES ENDING 1860 TO 1910, INCLUSIVE

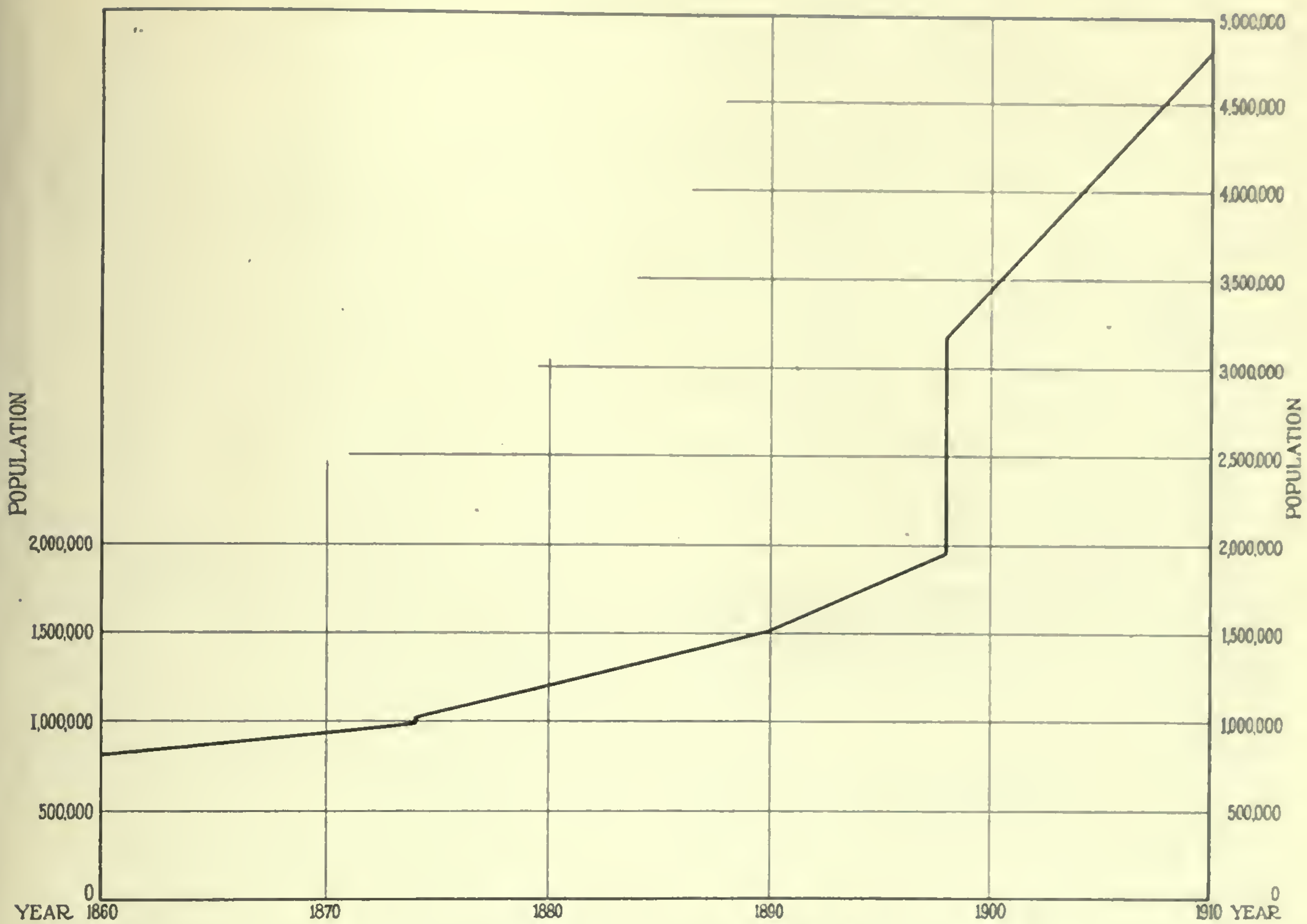
County	Area Sq. Miles	Population of County							Rural Population of County					Population in Cities and Villages					Population per Square Mile				
		Total	Per Cent in Rural Communities	Per Cent in Urban Communities	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease			
					Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860	
					No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Cent Per
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
United States Census, Decade Ending 1880																							
Fairf'ld, Conn.	631	112,042	49.7	50.3	16,766	17.6	34,566	44.6	55,723	—14,042	—20.1	—9,677	—14.8	56,319	30,808	120.8	44,243	366.3	177.6	26.6	17.6	54.8	44.6
Bergen .. N. J.	237	36,786	56.9	43,1	6,664	22.1	15,168	70.2	20,935	—9,187	—30.5	—683	—3.1	15,851	15,851	......	15,851	......	155.2	28.1	22.1	64.0	70.2
Essex .... "	127	189,929	20.1	79.9	46,090	32.0	91,052	92.1	38,036	8.604	29.2	19,977	111.6	151.893	37,486	32.8	71,075	87.9	1,495.5	362.9	32.0	717.0	92.1
Hudson . "	43	187.944	6.7	93.3	58,877	45.6	125,227	199.7	12,600	—1.058	—7.7	—2,058	—14.0	175,344	59,935	51.9	127,285	264.9	4,370.8	1,369.2	45.6	2,912.3	199.7
Hunterdon "	437	38,570	81.9	18.1	1,607	4.3	4.916	14.6	31,597	800	2.6	1.816	6.1	6.973	807	1.3	3.100	80.0	88.3	3.7	4.3	11.3	14.6
Mercer .. "	226	58.061	30.0	70.0	11,675	25.2	20,642	55.2	17,427	—1,940	—10.0	—1,794	—9.3	40.634	13.615	50.4	22,436	123.3	256.9	51.7	25.2	91.3	55.2
Middlesex "	312	52,286	53.0	47.0	7,257	16.1	17,474	50.2	27,733	623	2.3	6.479	30.5	24.553	6,634	37.0	10,995	81.1	167.6	23.3	16.1	56.0	50.2
Monmouth "	479	55.538	81.3	18.7	9,343	20.2	16,192	41.2	45,152	—1,043	—2.3	5,806	14.8	10.386	10,386	......	10,386	......	115.9	19.5	20.2	33 8	41 2
Morris .. "	475	50.861	84.4	15.6	7,724	17.9	16,184	46.7	42,949	—188	—0.4	8,272	23.8	7,912	7,912	......	7,912	......	107 1	16.3	17.9	34.1	46.7
Passaic .. "	196	68,860	16.4	83.6	22.444	48.4	39,847	137.3	11,297	—1.540	—12.0	1,870	19.8	57,563	23,984	71.4	37,977	193.9	351.3	114.5	48.4	203 3	137.3
Somerset. "	305	27,162	73.5	26.5	3,652	15.5	5,105	23.1	19.974	265	1.3	—2,083	—9.4	7,188	3,387	89.1	7,188	......	89.1	12.0	15.5	16.8	23.1
Sussex ... "	529	23,539	86.0	14.0	371	1.6	—307	—1.3	20,244	—521	—2.5	—1.778	—8.1	3.295	892	37.1	1.471	80.6	44.5	0.7	1.6	—0 6	—1.3
Union ... "	103	55.571	20.3	79.7	13,712	32.8	27,791	100.0	11,288	1,614	16.7	5.429	92.7	44.283	12.098	37.6	22.362	102.0	539.5	133.1	32.8	269 8	100.0
Warren .. "	362	36,589	62.8	37.2	2,253	6.6	8,156	28.7	22,991	551	2.5	—2.560	—10.0	13,598	1,702	14.3	10.716	371.8	101.1	6.3	6.6	22 6	28.7
Kings .. N. Y.	70	599,495	5.0	95.0	179,574	42.8	320,373	114.8	29.888	6,066	25.5	17,427	139.8	569,607	173,508	43.8	302.946	113.6	8,564.4	2,565.4	42.8	4,576 9	114.8
Nassau . "	274	37,647	90.4	9 6	6,513	20.9	10,684	39.6	34.025	6,666	24.4	7,062	26.2	3,622	—153	—4.1	3,622	......	137.4	23.8	20.9	39.0	39.6
New York "	63	1,206,299	.....	100.0	264.007	28.0	392,630	48.3	......	......	......	......	.....	1,206,299	264.007	28.1	392.630	48.3	19,147.6	—2,267.9	—10.6	—655 3	—3.5
Orange . "	834	88,220	49.8	50.2	7,318	9.1	24.408	38.2	43.909	—595	—1.3	—7,815	—15.1	44,311	7,913	21.7	32,223	266.6	105.8	8.8	9.1	29.3	38.2
Putnam "	233	15.181	82.5	17.5	—239*	—1.5	1,179	8.4	12,539	195	1.6	1.297	11.5	2,652	—434	—14.1	—118	—4.3	65.2	—1.0	—1 5	5.1	8 4
Queens . "	105	52.927	32.6	67.4	10,258	24.0	22,499	73.9	17,231	1,830	11.9	—13.197	—43.4	35,696	8,428	30.9	35.696	......	504.1	97.7	24.0	214.3	73.9
Richmond "	48	38.991	37.4	62.6	5,962	18.1	13,499	52.9	14,573	—6,362	—30.4	—10,919	—42.8	24.418	12,324	101.9	24,418	......	812 3	124.3	18.1	281 2	52 9
Rockland "	183	27,690	66.9	33.1	2.477	9.8	5,198	23.1	18,522	2,429	15.1	—1.247	—6.3	9,168	48	0.5	6,445	236.7	151 3	13.5	9.8	28.4	23.1
Suffolk .. "	924	53.888	72.5	27.5	6.964	14.8	10.613	24.5	39,082	8,202	26.6	—4,193	—9.7	14.806	—1,238	—7.7	14.806	.....	58.3	7.5	14 8	11.5	24.5
Westchester "	448	108.988	44.8	55 2	—22,360	—17.0	9.491	9.5	48.841	—30.930	—38.8	—29,944	—38.0	60,147	8.570	16.6	39,435	190.4	243.3	—38.0	—13.5	30.2	14.2
Totals, Conn.	631	112.042	49.7	50.3	16,766	17.6	34,566	44.6	55,723	—14.042	—20.1	—9,677	—14.8	56.319	30,808	120.8	44,243	366.3	177.6	26.6	17.6	54.8	44 6
Totals, N. J	3,831	881.696	36.5	63.5	191,669	27.8	387,447	78.4	322.223	—3,020	—0.9	38.693	13.6	559,473	194,689	10 3	348,754	26 0	230.1	50.0	27.8	101.1	78 4
Totals, N. Y.	3,182	2,229.326	11.6	88.4	460,474	26.0	810,574	57.1	258,600	—12,499	—4.6	—41.529	—13.8	1,970,726	472.973	31 6	852.103	76.2	700.6	144.8	26.0	254 7	57.1
Grand totals	7,644	3,223.064	19.7	80.3	668,909	26.2	1,232,587	61.9	636,546	—29,561	—4.4	—12,513	—1.9	2,586,518	698,470	37 0	1.245.100	92.8	421.6	87.5	26.2	161.3	61.9
United States Census, Decade Ending 1890																							
Fairf'ld, Conn.	631	150,081	38 4	61.6	38,039	34.0	72,605	93.7	57,650	1.927	3.5	—7.750	—11.8	92.431	36,112	64.1	80,355	665.4	237.8	60.2	34.0	115 0	93.7
Bergen .. N. J.	237	47,226	52.6	47.4	10.440	28.4	25.608	118.5	24.827	3,892	18.6	3.209	14.8	22.399	6,548	41.3	22,399	......	199.2	44.0	28.4	108 0	118.5
Essex ... "	127	256,098	20.4	79.6	66.169	34.8	157,221	159.0	52,318	14,282	37.5	34,259	191.4	203,780	51,887	34.2	122.962	152.1	2.016.5	521.0	34 8	1,238.0	159 0
Hudson . "	43	275,126	11.4	88,6	87,182	46.4	212.409	338.7	31,499	18,899	150.0	16,841	114 9	243,627	68,283	38.9	195,568	406.9	6,398.3	2,027.5	46 4	4,939.8	338.7
Hunterdon "	437	35,355	79.8	20.2	—3,215	—8.3	1,701	5.1	28.213	—3,384	—10.7	—1,568	—5.3	7,142	169	2.4	3.269	84.4	80.9	—7.4	—8 3	3 9	5 1
Mercer .. "	226	79,978	20.8	79,2	21,917	37.7	42,559	113.7	16,635	—792	—4.5	—2,586	—13.5	63,343	22,709	55.9	45,145	248.1	353.9	97.0	37 7	188 3	113 7
Middlesex "	312	61.754	40.2	59.8	9,468	18.1	26.942	77.4	24.796	—2.937	—10.6	3,542	16.7	36.958	12,405	50.5	23,400	172.6	197.9	30.3	18 1	86.3	77 4
Monmouth "	479	69.128	67.6	32.4	13,590	24.5	29.782	75.7	46.746	1.594	3.5	7,400	18.8	22,382	11,996	115.5	22,382	......	144.3	28.4	24 5	62 2	75 7
Morris .. "	475	54,101	78.9	21.1	3,240	6.4	19.424	56.0	42,696	—253	—0.6	8.019	23 1	11,405	3.493	44.1	11,405	......	113.9	6 8	6 4	40.9	56 0
Passaic .. "	196	105,046	13.1	86.9	36,186	52.5	76.033	262.1	13,671	2.374	21.0	4.244	45 0	91,375	33.812	58.7	71,789	366.5	535.9	184 6	52 5	387.9	262.1
Somerset "	305	28.311	67.7	32.3	1.149	4.2	6.254	28.4	19,156	—818	—4.1	—2,901	—13.2	9.155	1,967	27.4	9,155	.....	92 8	3 7	4 2	20.5	28 4
Sussex ... "	529	22.250	79.7	20.3	—1.280	—3.4	—1,587	—6.7	17,744	—2.500	—12.3	—4.278	—19.4	4,515	1.220	3.7	2,691	147.5	42 1	—2 4	—3 4	—3 0	—6 7
Union ... "	103	72.467	7.5	92.5	16,896	30.4	44,687	160,9	5,399	—5.889	—52.2	—460	—7.9	67,068	22,785	51.4	45,147	205.9	703 6	164 1	30 4	433 9	160 9
Warren .. "	362	36.553	57.1	42.9	—36	—0.1	8,120	28.6	20.890	—2.101	—0.9	—4,661	—18 2	15,663	2.065	15.2	12,781	443 5	101.1	......	0 0	22.6	28 6
Kings ... N. Y.	70	838,547	2.1	97.9	239.052	39.9	559.425	200.4	17,869	—12,019	—40.2	5,408	43.4	820,678	251.071	44.1	554.017	207 8	11,979.5	3.415 1	39 9	7,992.0	200 4
Nassau . "	274	45,760	73.2	26.8	8.113	21.6	18.797	69.7	33,482	—543	—1.6	6.519	24 2	12,278	8,656	239.0	12.278	.....	167.0	29 6	21 6	68.6	69 7
New York "	63	1.515,301	....	100.0	309.002	25.6	701,632	86.2	......	......	......	......	.....	1,515,301	309,002	25.6	701,632	86 2	24,052 4	4,904 8	25 6	5,560.1	30.1
Orange .. "	834	97,859	41.5	58.5	9.639	10.9	34,047	53.4	40.620	—3.289	—7.5	—11,104	—21.5	57,239	12,928	29.2	45,151	373 5	117 3	11 5	10 9	40 8	53 4
Putnam . "	233	14,849	100.0	.....	—332	—2.2	847	6.0	14.849	2.320	18.5	3,617	32 2	....	—2,652	.....	—2,770	.....	63 7	—1 5	—2 2	3 6	6.0
Queens "	105	82,299	28.6	71.4	29,372	55.5	51.871	170.5	23.501	6,320	36 7	—6,877	—22.6	58,798	23,102	64.7	58,798	.....	783 8	279 7	55 5	494 0	170.5
Richmond "	48	51.693	27.2	72.8	12,702	32.6	26.201	102.8	14.049	—524	—3.6	—11,443	—44.9	37.644	13,226	54 2	37,644	.....	1,076.9	264 6	32 6	345 8	102 8
Rockland "	182	35,162	60.0	40 0	7,472	27.0	12.670	56.3	21,088	2,566	13.9	1.319	6.7	14.074	4.906	53 5	11,351	416.9	192 1	40 8	27 0	60.2	56 3
Suffolk "	924	62,491	74.1	25.9	8.603	16.0	19.216	44.4	46,287	7.205	18.4	3,012	7.0	16.204	1.398	9 4	16,204	..	67 6	9 3	16 0	30.8	44 4
Westchester "	448	146,772	32.2	67.8	37.784	34.7	47,275	47.5	47,307	—1,534	—3.1	—31.478	—40 0	99.465	39,318	63.4	78.753	380 2	327 6	84 3	34 7	114 5	53 7
Totals Conn.	631	150.081	38.4	61.6	39.039	34.0	72,605	93.7	57,650	1,927	3.5	—7,750	—11.8	92,431	36,112	64 1	80.355	665.4	237 8	60 2	34 0	115 0	93 7
Totals, N. J	3,831	1.143.402	30 1	69.9	261,706	29.7	649.153	131.3	344,590	22.367	69.4	61.060	21.5	798,812	239.339	42.8	588,093	279 1	298 5	68 5	29 7	169 5	131 3
Totals, N. Y	3.182	2,890.733	9.0	91.0	661,407	29.7	1,471,981	103.8	259,052	452	0 2	—41,077	—13.7	2,631,681	660,955	33 5	1,513,058	135.3	908 6	208 0	29 7	462 7	103 8
Grand totals	7.644	4,184,216	15.8	84.2	961,152	29.8	2.193.739	110.2	661,292	24,746	3.9	12.233	1.9	3.522.924	936.406	36.2	2,181,506	162.6	547.3	125 7	29 8	287 0	110 2

* Minus sign (—) denotes decrease.

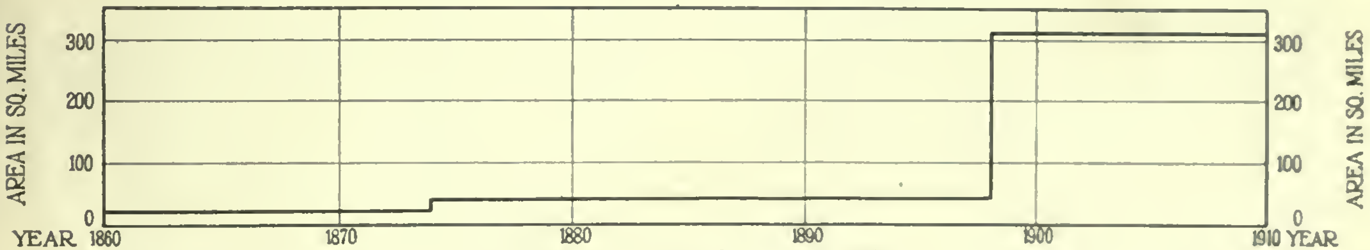
TABLE CDLXIV (Concluded). STATISTICS OF POPULATION OF COUNTIES IN THE STATES OF CONNECTICUT, NEW JERSEY AND NEW YORK WITHIN 50 MILES OF NEW YORK CITY AS SHOWN BY THE UNITED STATES CENSUS, DECADES ENDING 1860 to 1910, INCLUSIVE

County	Area Sq. Miles	Population of County							Rural Population of County					Population in Cities and Villages					Population per Square Mile				
		Total	Per Cent in Rural Communities	Per Cent in Urban Communities	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease			
					Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860	
					No	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
United States Census. Decade Ending 1900																							
Fairf'ld, Conn.	631	184.203	31 8	68.2	34.122	22.7	106.727	137.8	58.581	931	1.6	—6.819	—10.4	125,622	33.191	35.9	113.546	940.3	291.9	54.1	22.7	169.1	137.8
Bergen ..N.J	237	78,441	25.2	74.8	31.215	66.1	56.823	262.9	19.758	—5.069	—20.4	—1.860	—8 6	58.683	36.284	161.9	58.683	....	331.0	131.8	66.1	239.8	262.9
Essex ... "	127	359.053	4.9	95.1	102.955	40.2	260,176	263.1	17.509	—34.809	—66.5	—550	—3 0	341,544	137.764	67.6	260.726	322.6	2,827.2	810.7	40.2	2.048 7	263.1
Hudson.. "	43	386,048	6.8	93.2	110.922	40.3	323.331	515.5	26.084	—5.415	—17.2	11.426	77.9	359,964	116.337	47.8	311,905	649 0	8.977.9	2,579.6	40.3	7.519.4	515.5
Hunterdon "	437	34.507	66.4	33.6	—816*	—2.4	853	2.5	22.921	—5.289	—18.7	—6.857	—23.0	11,583	4.441	62.2	7.710	199 1	79.0	—1.9	—2.4	2.0	2.5
Mercer .. "	226	95.365	15.4	84 6	15.387	19.2	57,946	154.9	14.697	—1.938	—11.6	—4.521	—23.5	80.668	17.325	27.4	62.470	343.3	422 0	68.1	19.2	256.4	154.9
Middlesex "	312	79.762	31.9	65.1	18.008	29.2	44.950	129.1	27 820	3.024	12.2	6.566	30.9	51,942	14,984	40.5	38.384	283.1	255.6	57.7	29.2	144.0	129.1
Monmouth "	479	82,057	55.2	44.8	12.929	18.7	42,711	108.6	45.322	—1.424	—3.0	5.976	15.2	36,735	14.353	64.1	36.735	....	171.3	27.0	18.7	89.2	108.6
Morris... "	475	65.156	51.3	48 7	11,055	20.4	30.479	87.9	33.415	—9.281	—21.7	—1,262	—3.6	31,741	20,336	178.3	31.741	.....	137 2	23.3	20.4	61.2	87.9
Passaic .. "	196	155,202	12 1	87 9	50,156	47.7	126.189	434.9	18.749	5,078	37.1	9.322	98.9	136.453	45.078	49.3	116.867	596.7	791.8	255.9	47.7	643.8	434.9
Somerset. "	305	32.918	46.6	53 4	4,637	16.4	10.891	49.4	15,346	—3,810	—19.8	—6.711	—30.4	17,002	8,447	92.3	17.602	....	108 0	15.2	16.4	35.7	49.4
Sussex.. "	529	24,134	74.0	26.0	1,875	8.4	288	1.1	17.851	107	0.6	—4,171	—18.9	6,283	1.768	39.2	4.459	244.5	45.6	3.5	8.4	0.5	1.1
Union .. "	103	99.353	15.3	84.7	26,886	37.1	71,573	257.6	15,232	9.833	182.1	9,373	160.0	84.121	17,053	25.4	62.200	283.7	964.6	261.0	37.1	694.9	257.6
Warren.. "	362	37.781	52 6	47.4	1,228	3.3	9,348	32.9	19,891	—909	—4.8	—5.660	—22.1	17,890	2,227	14.2	15,008	520.7	104.4	3.3	3.3	25.9	32.9
Kings...N. Y.	70	1,166.582	.....	100.0	328.035	39.1	887,460	317.9	....	—17.869	......	—12,461	......	1,166.582	345.904	42.1	899.921	337.5	16.665.7	4.686.2	39.1	12.678.2	317.9
Nassau.. "	274	55.448	80.3	19.7	9.688	21.2	28,485	105.6	41,515	11.033	32.9	17,552	65.1	10.933	—1,345	—10.9	10.933	....	202.4	35.4	21.2	104.0	105.6
New York "	63	2,050,600	.....	100.0	535.299	35.3	1.236,931	152.0	....	....	......	....	......	2,050,600	535.299	35.3	1,236.931	152.0	32,549.2	8,496.8	35.3	14,056.9	76.0
Orange... "	834	103.859	37.4	62.6	6,000	6.1	40,047	62.8	38.842	—1.778	—4.4	—12,882	—24.9	65.017	7.778	13.6	52,929	437.9	124.5	—7.2	6.1	48.0	62.8
Putnam.. "	233	13.787	71.8	28.2	—1.062	—7.2	—215	—1.6	9.904	—4.945	—33.3	—1.328	—11.8	3.883	3,883	......	1.113	40.2	59.2	—4 5	—7.2	—0.9	—1.6
Queens... "	105	152.999	.....	100.0	70,700	85.9	122.571	402.8	....	—23,501	......	—30.428	......	152.999	91.201	160.2	152.999	....	1.457.1	673.3	85.9	1,167.3	402.8
Richmond "	48	67,021	.....	100.0	15.328	29.7	41,529	162.9	....	—14.049	......	—25.492	......	67.021	29,377	78.0	67.021	....	1.396.2	319.3	29.7	865.1	162.9
Rockland. "	183	38.298	53.0	47.0	3,136	8.9	15,806	70.3	20,296	—792	—3.8	527	2.7	18.002	3,928	27.9	15.279	561.1	209.3	17.2	8.0	86.4	70.3
Suffolk... "	924	77,582	80.5	19.5	15.091	24.2	34.307	79.3	62,432	16.145	34.9	19,157	44.3	15.150	—1,054	—6.5	15,150	....	84.0	16.4	24.2	37.2	79.3
Westchester"	448	184.257	23.7	76.3	37.485	25.5	84,760	85.2	43.612	—3.695	—7.8	—35.173	—44.6	140.645	41.180	41 4	119.933	579.0	411.3	83.7	25.5	198 2	93 0
Totals, Conn.	631	184.203	31.8	68.2	34.122	22.7	106.727	137.8	58.581	931	1.6	—6.819	—10 4	125.622	33.191	35 9	113.546	940 3	291.9	54 1	22 7	169.1	137 8
Totals. N. J.	3,831	1.529.807	19.3	80.7	386.405	33 8	1.035.558	209.5	294.598	—49.992	—14 5	11.068	39.0	1.235.200	436,397	54.6	1.021.490	486.2	399 3	100 8	33.8	270 3	209.5
Totals. N. Y.	3.182	3.910.433	5 6	94.4	1.019.700	35.3	2.491,681	175.6	219.601	—39.451	—15.2	—80.528	—26.8	3.690.832	1.059.151	40 2	2.572.209	229 9	1.228 9	320.3	35.3	783 0	175 6
Grand totals	7,644	5.624.443	10.2	89.8	1.440.227	34 2	3.633,966	182.5	572,780	—88,512	—13.4	—76.279	—11.8	5,051,663	1.528,739	43 4	3.710.245	276.6	735 7	188.4	34 2	475 4	182.5
United States Census. Decade Ending 1910																							
Fairf'ld.Conn.	631	245.322	27.3	72.7	61,119	33.2	167,846	216.6	67.026	8.445	14.4	1.626	2.5	178,296	52,674	41 9	166.220	1,376 4	388 8	96 9	33.2	266 0	216 6
Bergen ..N.J.	237	138,002	17.4	82.6	59,561	75.9	116,384	538.4	24.046	4.288	21.7	2.428	11.2	113.956	55,273	94 2	113.956	......	582.3	251.3	75.9	491 1	538.4
Essex.... "	127	512.886	4.0	96.0	153,833	42.8	414.009	417.7	20.728	3,219	18.4	2,669	14.9	492.158	150.614	44.1	411.340	509.0	4,038.5	1,211.3	42.8	3,260 0	418.7
Hudson.. "	43	537,231	7.4	92.6	151,183	39.2	474,514	756.6	39.683	13,599	52.1	25.025	170.7	497,548	137.584	38.2	449.489	935 3	12.493 8	3.515.9	39.2	11,035.3	756.6
Hunterdon "	437	33.569	61 8	38.2	—938	—2.7	—85	—0.3	20,735	—2.189	9.5	—9.046	—30.4	12,834	1,251	10.8	8.961	231.4	76.8	—2.2	—2.7	—0 2	—0.3
Mercer... "	226	125.657	15.9	84.1	30,292	31.8	88,238	235.8	20.032	5,335	36.3	811	4.2	105.625	21,957	30.9	87,427	480.4	556.0	134.0	31.8	390.4	235.8
Middlesex "	312	114.426	26.9	73.1	34,664	43.5	79,614	228.7	30.764	2,944	10.6	9.510	44.7	83.662	31.720	61.6	70.104	517.1	366.7	111.1	43.5	255.1	228 7
Monmouth "	479	94.734	41.9	58.1	12,677	15.4	55.388	140.8	39.705	—5,617	—12.4	359	0.9	55.029	18.294	49.8	55.029	......	197.8	26.5	15.4	115.7	140.8
Morris... "	475	74.704	43.7	56.3	9,548	14.7	40.027	115.4	32,621	—794	—2.4	—2,056	—5.9	42,083	10.342	32 6	42.083	...	157.3	20.1	14.7	84.3	115.4
Passaic... "	196	215,902	11.1	88.9	60,700	39.1	186,889	644.2	23.911	5.162	27.5	14,484	153.6	191.991	55,538	40.7	172.405	880.2	1.101.5	309.7	39.1	953.5	644.2
Somerset. "	305	38.820	46.3	53.7	5,872	17.8	16.763	76.0	17.962	2.616	17.4	—4.095	—18.6	20,858	3.256	18.5	20.858	......	127.3	19.3	17.8	55.0	76 0
Sussex... "	529	26,781	68.6	31.4	2,647	11.0	2,935	12.3	18,378	527	2.9	—3.644	—16.5	8.403	2.120	33.7	6.579	360.7	50.6	5.0	11 0	5.5	12 3
Union ... "	103	140.197	9.2	90.8	40,844	41.1	112.417	401.7	12.905	—2,327	—15.3	7.046	120.3	127,292	43.171	51 3	105.371	480.7	1.361.1	396.5	41.1	1,091.4	404 7
Warren.. "	362	43,187	49.2	50.8	5,406	14.3	14.754	51.9	21.238	1.347	6.8	—4.313	—16.9	21.949	4.059	22 7	19.067	661.6	119.3	14.9	14.3	40.8	51.9
Kings...N. Y.	70	1.634,351	.....	100.0	467,769	40.1	1.355.229	485.5	....	....	......	—12.461	......	1.634,351	467,769	40.1	1,367.690	512.9	23,348.3	6.682.6	40.1	19,360.8	485 5
Nassau .. "	274	83.930	73.4	26.6	28,482	51.4	56.967	211.3	61,607	17,092	38.4	34,644	128.5	22,323	11,390	101.2	22,323	......	306.3	103.9	51.4	207.9	211.3
New York "	63	2.762,522	.....	100.0	711,922	34.7	1.918,853	239.5	....	....	......	....	......	2.762.522	711,922	34.7	1.918,853	239.5	43.849 5	11,300.3	34.7	25,357.2	137.1
Orange... "	834	116.001	38 3	61.7	12.142	11.7	52,189	81.8	44.460	5.618	14.5	—7,264	—14 0	71.541	6,524	10.0	59.453	491.8	139.1	14.6	11.7	62.6	81 8
Putnam.. "	233	14.665	68.6	31.4	878	6.4	663	4.7	10.055	151	1.5	—1,177	—10.5	4.610	727	1.9	1,840	66.4	62.9	3.7	6.4	2.8	4.7
Queens... "	105	284.041	.....	100 0	131.042	85.6	253.613	833.5	....	....	......	—30.428	......	284,041	131.042	85.6	284.041	....	2.705.1	1,248.0	85.6	2.415.3	833 5
Richmond "	48	85.969	.....	100.0	18.948	28.3	60.477	237.2	....	....	......	—25.492	......	85.969	18.948	28.3	85.969	....	1.791.0	394.8	28.3	1.259.9	237.2
Rockland. "	183	46,873	50.6	49.4	8.575	22.4	24.381	108.4	23.703	3.407	16 8	3.934	19.9	23.170	5.168	28.7	20.447	750.9	256.1	46 8	22.4	133.2	108.4
Suffolk... "	924	96.138	78.7	21.3	18.556	23.9	52.863	122.2	75.676	13.244	21.2	32,401	74.9	20.462	5.312	35.1	20.462	......	104.0	20 1	23.9	57 2	122.2
Westchester"	448	283.055	13.7	86.3	98,798	53.6	183.558	184.5	38.861	—4,751	—10 9	—39.924	—39.7	244.194	103.549	73.6	223,482	1.079 0	631.8	220.5	53 6	418 7	196 5
Totals, Conn.	631	245.322	27.3	72.7	61,119	33.2	167.846	216.6	67.026	8.445	14 4	1.626	2.5	178.296	52.674	41.9	166.220	1.376.4	388 8	96.9	33.2	266 0	216.6
Totals. N. J.	3.831	2.096.096	15.4	84.6	566.289	37.0	1.601.847	321.1	322.708	28.110	9.5	39.178	13.8	1,773.388	538.179	43.6	1.562.669	741.6	547.1	147 8	37.0	418 1	324 1
Totals. N. Y.	3.182	5,407.545	4.7	95.3	1.497,112	38.3	3.988.793	281.1	254.362	34.761	15 8	—45.767	—15.2	5.153.183	1,462,351	39 6	4.034.560	360.7	1,699.4	470 5	38.3	1.253.5	281 1
Grand totals	7.644	7.748.963	8.3	91.7	2.124,520	37.8	5,758.486	289.3	644.096	71.316	12.5	—4.963	—0.8	7.104.867	2.053.204	40 6	5.763.449	329.6	1.013.7	278 0	37.8	753 4	289.3

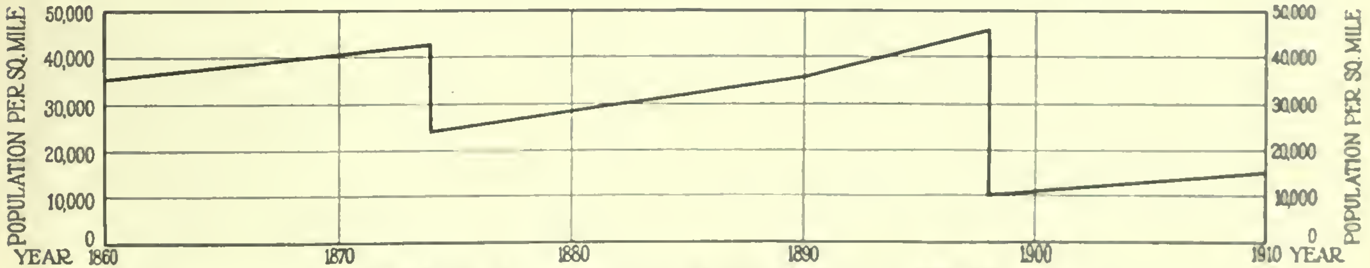
* Minus sign (—) denotes decrease.



Population of New York City 1860-1910



Area of New York City 1860-1910



Population per Square Mile of New York City 1860-1910

FIG. 704. CHANGES IN POPULATION AND AREA OF THE CITY OF NEW YORK, FROM UNITED STATES CENSUS AND MUNICIPAL REPORTS, 1860-1910

TABLE CDLXV. INCREASES IN THE POPULATION OF BOSTON AND OF THE INDUSTRIAL ZONE OUTSIDE OF BOSTON
1860 1910

Decade	Increase in Total Population of Zone		Increase in the Population of the City of Boston		Increase in the Population of the Industrial Zone Outside of the City of Boston					
							Increase in Cities and Villages		Increase in Rural Districts	
	Total Increase	Per Cent of Increase	Total Increase	Per Cent of Increase	Total Increase	Per Cent of Increase in Total Population	Total Increase	Per Cent of Total Increase Outside of the City of Boston	Total Increase	Per Cent of Total Increase Outside of the City of Boston
1	2	3	4	5	6	7	8	9	10	11
1860–1870	240,281	18.7	72,686	40.9	167,595	69.75	175,391	104.65	—7,796*	—4.65
1870–1880	361,497	23.7	112,313	44.8	249,184	68.93	245,491	98.52	3,693	1.48
1880–1890	491,040	26.0	85,638	23.6	405,402	82.56	442,155	109.07	—36,753	—9.07
1890–1900	604,872	25.4	112,415	25.1	492,457	81.42	487,254	98.94	5,203	1.06
1900–1910	611,731	20.5	109,693	19.6	502,038	82.07	503,213	100.23	—1,175	—0.23
Totals	2,309,421	179.9	492,745	277.1	1,816,676	78.66	1,853,504	102.03	—36,828	—2.03

* Minus sign (—) denotes decrease.

Philadelphia 19.87 per cent, while Chicago's portion was 9.34 per cent.

Though numerically less, Chicago's percentage of increase in the population outside the city was slightly greater than that of Philadelphia.

701.30 Comparative Population and Density of the Industrial Zones of Chicago, New York, Boston and Philadelphia: A comparative statement showing the total population and density of population of the industrial zones of the four cities under consideration is presented, by decades from 1860 to 1910, in table CDLXIX.

In order of total population at each of the six census years, the leading cities, including their industrial zones, are New York, Philadelphia, Boston and Chicago, though the figures for Philadelphia and Boston in 1910 were very close. In order of area of zones, Philadelphia includes 10,698 square miles, New York 7,644, Boston 7,344, and Chicago 6,681.

New York stands first in density of population, followed in order by Boston, Chicago and Philadelphia. From 1860 to 1910, the population of the New York zone increased 3.89 times. The corresponding factor for Philadelphia is 2.36 and for Boston 2.80, while Chicago leads the other cities in this respect with a factor of 8.59. The total population of the four cities in 1910 had increased to an amount 3.48 times that in 1860.

In 1860, the proportion which the population of each city bore to the combined population of the four cities was for New York 38.74 per cent, for Philadelphia 29.65 per cent, for Boston 24.98 per cent and for Chicago 6.63 per cent. In 1910, New York's proportion of the total was 43.38 per cent, Philadelphia's 20.12 per cent, Boston's 20.11 per cent, and Chicago's 16.39 per cent.

In 1860, the average density of population per square mile for the four cities was 158.73, and in 1910 it was 551.91. During the same period, Chicago's density of population per square mile increased from 51.0 to 438.2.

701.31 Comparative Increases in the Urban Population of the Industrial Zones of Chicago, New York, Boston and Philadelphia: The numerical and percentage increases in the total urban population of the industrial zones of the four cities under consideration and of each industrial zone are shown, by decades from 1860 to 1910, in table CDLXX.

While there is no retrogression during this period in the numerical volume of the combined increases, the maximum percentage increase was attained in the decade from 1880 to 1890. The first two decades of the period increased to this point, while the last two decades declined from it.

Individually, New York advanced in its percentages of increase throughout the 50 years, Philadelphia and Boston dropped, while Chicago rose to its maximum in the middle decade and then receded as in the case of the combined total.

The factor of increase of the combined total, as between the first decade and the last, was 3.19; for New York it was 3.76, for Chicago 3.24, for Philadelphia 2.56 and for Boston 2.47.

The numerical increases for the Chicago zone place that city fourth during the first and second decades, and thereafter it is second only to New York, which leads the other three cities throughout the entire period.

701.32 Increases in the Population of the Industrial Zones of Chicago, New York, Boston and Philadelphia: The numerical and percentage changes from 1860 to 1910 in the total population of the four largest industrial zones, the increase in population of the largest city of the zone, and the change in population of the industrial zone outside of the largest city are shown by table CDLXXI.

To the total increase, New York contributed 45.25 per cent, Chicago 20.33 per cent, Boston 18.15 per cent and Philadelphia 16.27 per cent. In the numerical increases in the population of the largest cities of the respective zones, the order is New York, Chicago, Philadelphia and Boston. Of the total combined increases of the four largest cities, New York alone supplied 52.67 per cent, Chicago 27.66 per cent, Philadelphia 13.10 per cent and Boston 6.57 per cent. In percentage of total increase in population of the largest city of each zone, Chicago was first with 80.26, New York 68.65, Philadelphia 47.48 and Boston 21.34.

In the combined increase in the population of the industrial zone outside the largest city, the percentage for Boston was 34.80, for New York 34.58, for Philadelphia 20.84 and for Chicago 9.78.

TABLE CDLXVI. STATISTICS OF POPULATION OF COUNTIES IN THE STATES OF CONNECTICUT, MASSACHUSETTS, NEW HAMPSHIRE AND RHODE ISLAND, WITHIN 50 MILES OF BOSTON, AS SHOWN BY THE UNITED STATES CENSUS, DECADES ENDING 1860 TO 1910, INCLUSIVE

County	Area Sq. Miles	Population of County							Rural Population of County*					Population of Cities and Villages					Population per Square Mile				
		Total	Per Cent in Rural Communities	Per Cent in Urban Communities	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease			
					Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860	
					No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
CONNECTICUT—1860																							
Windham	541	34,279	35.5	64.5	3,198	10.3	......	......	12,179	......	......	......	......	22,100	......	......	......	......	63.4	......	......	......	......
Totals, Conn.	541	34,279	35.5	64.5	3,198	10.3	......	......	12,179	......	......	......	......	22,100	......	......	......	......	63.4	......	......	......	......
MASSACHUSETTS—1860																							
Bristol	567	93,794	17.4	82.6	17,602	23.1	......	......	16,329	......	......	......	......	77,465	......	......	......	......	165.4	......	......	......	......
Essex	497	165,611	15.6	84.4	34,311	26.1	......	......	25,823	......	......	......	......	139,788	......	......	......	......	333.2	......	......	......	......
Middlesex	842	216,354	19.0	81.0	54,971	34.1	......	......	41,146	......	......	......	......	175,208	......	......	......	......	256.9	......	......	......	......
Norfolk	422	109,950	9.7	90.3	31,058	39.4	......	......	10,613	......	......	......	......	99,337	......	......	......	......	260.5	......	......	......	......
Plymouth	675	64,768	33.6	66.4	9,071	16.3	......	......	21,730	......	......	......	......	43,038	......	......	......	......	95.9	......	......	......	......
Suffolk	29	192,700	0.8	99.2	48,183	33.3	......	......	1,465	......	......	......	......	191,235	......	......	......	......	6,644.8	......	......	......	......
Worcester	1,556	159,659	32.6	67.4	28,870	22.1	......	......	51,982	......	......	......	......	107,677	......	......	......	......	102.6	......	......	......	......
Totals, Mass.	4,588	1,002,836	16.9	83.1	224,066	28.8	......	......	169,088	......	......	......	......	833,748	......	......	......	......	218.6	......	......	......	......
NEW HAMPSHIRE—1860																							
Hillsboro......	895	62,140	51.4	48.6	4,662	8.1	......	......	31,968	......	......	......	......	30,172	......	......	......	......	69.4	......	......	......	......
Rockingham...	691	50,122	74.8	25.2	928	1.9	......	......	37,478	......	......	......	......	12,644	......	......	......	......	72.5	......	......	......	......
Totals, N. Hamp.	1,586	112,262	61.9	38.1	5,590	5.2	......	......	69,446	......	......	......	......	42,816	......	......	......	......	70.8	......	......	......	......
RHODE ISLAND—1860																							
Bristol	25	8,907	11.2	88.8	393	4.6	......	......	1,000	......	......	......	......	7,907	......	......	......	......	356.2	......	......	......	......
Kent	174	17,303	7.3	92.7	2,235	14.8	......	......	1,264	......	......	......	......	16,039	......	......	......	......	99.4	......	......	......	......
Providence	430	107,799	4.0	96.0	20,273	23.2	......	......	4,362	......	......	......	......	103,437	......	......	......	......	250.7	......	......	......	......
Totals R.Isld.	629	134,009	4.9	95.1	22,901	20.6	......	......	6,626	......	......	......	......	127,383	......	......	......	......	213.0	......	......	......	......
Grand totals	7,344	1,283,386	20.0	80.0	255,755	24.9	......	......	257,339	......	......	......	......	1,026,047	......	......	......	......	174.8	......	......	......	......
CONNECTICUT—1870																							
Windham	541	38,518	31.0	69.0	4,239	12.4	4,239	12.4	11,922	—257	—2.1	—257	—2.1	26,596	4,496	20.3	4,496	20.3	71.2	7.8	12.4	7.8	12.4
Totals, Conn.	541	38,518	31.0	69.0	4,239	12.4	4,239	12.4	11,922	—257	—2.1	—257	—2.1	26,596	4,496	20.3	4,496	20.3	71.2	7.8	12.4	7.8	12.4
MASSACHUSETTS—1870																							
Bristol......	567	102,886	16.5	83.5	9,092	9.7	9,092	9.7	17,017	688	4.2	688	4.2	85,869	8,404	10.8	8,404	10.8	181.4	16.0	9.7	16.0	9.7
Essex.........	497	200,843	11.9	88.1	35,232	21.3	35,232	21.3	23,981	—1,842	—7.1	—1,842	—7.1	176,862	37,074	26.5	37,074	26.5	404.1	70.9	21.3	70.9	21.3
Middlesex	842	274,353	15.7	84.3	57,999	26.8	57,999	26.8	43,033	1,887	4.6	1,887	4.6	231,320	56,112	32.0	56,112	32.0	325.8	68.9	26.8	68.9	26.8
Norfolk........	422	89,443	13.7	86.3	—20,507†	—18.7	—20,507	—18.7	12,217	1,604	15.1	1,604	15.1	77,226	—22,111	—22.3	—22,111	—22.3	211.9	—48.6	—18.7	—48.6	—18.7
Plymouth	675	65,365	35.1	64.9	597	0.9	597	0.9	22,928	1,198	5.5	1,198	5.5	42,437	—601	—1.4	—601	—1.4	96.8	0.9	1.0	0.9	1.0
Suffolk.........	29	270,802	0.6	99.4	78,102	40.5	78,102	40.5	1,729	264	1.8	264	1.8	269,073	77,838	40.7	77,838	40.7	9,338.0	2,693.2	40.5	2,693.2	40.5
Worcester	1,556	192,716	25.0	75.0	33,057	20.7	33,057	20.7	48,255	—3,727	—7.2	—3,727	—7.2	144,461	36,784	34.2	36,784	34.2	123.8	21.2	20.7	21.2	20.7
Totals, Mass.	4,588	1,196,408	14.1	85.9	193,572	19.3	193,572	19.3	169,160	72	......	72	......	1,027,248	193,500	23.2	193,500	23.2	260.8	42.2	19.3	42.2	19.3
NEW HAMPSHIRE—1870																							
Hillsboro	895	64,238	42.9	57.1	2,098	3.4	2,098	3.4	27,553	—4,415	—13.8	—4,415	—13.8	36,685	6,513	21.6	6,513	21.6	71.8	2.4	3.4	2.4	3.4
Rockingham...	691	47,297	73.3	26.7	—2,825	—5.6	—2,825	—5.6	34,649	—2,829	—7.5	—2,829	—7.5	12,648	4	......	4	......	68.4	—4.1	—5.6	—4.1	—5.6
Totals, N. Hamp.	1,586	111,535	55.8	44.2	—727	—0.6	—727	—0.6	62,202	—7,244	—10.4	—7,244	—10.4	49,333	6,517	15.2	6,517	15.2	70.3	—0.5	—0.6	—0.5	—0.6
RHODE ISLAND—1870																							
Bristol.........	25	9,421	11.8	88.2	514	5.8	514	5.8	1,111	111	11.1	111	11.1	8,310	403	5.1	403	5.1	376.8	20.6	5.8	20.6	5.8
Kent	174	18,595	6.1	93.9	1,292	7.5	1,292	7.5	1,133	—131	—10.4	—131	—10.4	17,462	1,423	8.9	1,423	8.9	106.8	7.4	7.5	7.4	7.5
Providence	430	149,190	2.7	97.3	41,391	38.4	41,391	38.4	4,015	—347	—8.0	—347	—8.0	145,175	41,738	40.4	41,738	40.4	346.9	96.2	38.4	96.2	38.4
Totals R.Isld.	629	177,206	3.5	96.5	43,197	32.2	43,197	32.2	6,259	—367	—5.5	—367	—5.5	170,947	43,564	34.2	43,564	34.2	281.7	68.7	32.2	68.7	32.2
Grand totals.	7,344	1,523,667	16.4	83.6	240,281	18.7	240,281	18.7	249,543	—7,796	—3.0	—7,796	—3.0	1,274,124	248,077	24.2	248,077	24.2	207.4	32.6	18.7	32.6	18.7

* In the states of Connecticut, Massachusetts, New Hampshire and Rhode Island, all "towns" having 2,500 or more inhabitants are classed as urban population; less than 2,500, as rural communities.

† Minus sign (—) denotes decrease.

TABLE CDLXVI (Continued). STATISTICS OF POPULATION OF COUNTIES IN THE STATES OF CONNECTICUT, MASSACHUSETTS, NEW HAMPSHIRE AND RHODE ISLAND, WITHIN 50 MILES OF BOSTON, AS SHOWN BY THE UNITED STATES CENSUS, DECADES ENDING 1860 TO 1910, INCLUSIVE

County	Area Sq. Miles	Population of County							Rural Population of County*					Population of Cities and Villages					Population per Square Mile				
		Total	Per Cent in Rural Communities	Per Cent in Urban Communities	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease			
					Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860	
					No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
CONNECTICUT—1880																							
Windham	541	43,856	25.4	74.6	5,338	13.9	9,577	27.9	11,133	—789	—6.6	—1,046	—8.6	32,723	6,127	23.0	10,623	48.1	81.1	9.9	13.9	17.7	27.9
Totals, Conn	541	43,856	25.4	74.6	5,338	13.9	9,577	27.9	11,133	—789	—6.6	—1,046	—8.6	32,723	6,127	23.0	10,623	48.1	81.1	9.9	13.9	17.7	27.9
MASSACHUSETTS—1880																							
Bristol	567	139,040	10.8	89.2	36,154	35.1	45,246	48.2	15,044	—1,973	—11.6	—1,285	—7.9	123,996	38,127	44.4	46,531	60.1	245.2	63.8	35.1	79.8	48.2
Essex	497	241,535	8.6	91.4	43,692	21.8	78,924	47.7	21,068	—2,913	—12.1	—4,755	—18.4	223,467	46,605	26.4	83,679	59.9	492.0	87.0	21.8	158.8	47.7
Middlesex	837	317,830	13.6	86.4	43,477	15.8	101,476	46.9	43,106	73	0.2	1,960	4.8	274,724	43,404	18.8	99,516	56.8	379.7	53.9	16.5	122.8	47.8
Norfolk	410	96,507	17.9	82.1	7,064	8.0	—13,433†	—12.2	17,301	5,084	41.6	6,688	63.0	79,206	1,980	2.6	—20,131	—20.3	235.4	23.5	11.1	—25.1	—9.6
Plymouth	675	74,018	31.2	68.8	8,653	13.2	9,250	14.3	23,095	167	0.7	1,365	6.3	50,923	8,486	20.0	7,885	18.3	109.6	12.8	13.2	13.7	14.3
Suffolk	46	387,927	0.9	99.1	117,125	43.3	195,227	101.3	3,306	1,577	91.3	1,841	125.7	384,621	115,548	42.9	193,386	101.1	8,433.1	—904.9	—9.7	1,788.3	26.9
Worcester	1,556	226,897	20.3	79.7	34,181	17.7	67,238	42.1	46,125	—2,130	—4.4	—5,857	—11.3	180,772	36,311	25.1	73,095	67.9	145.8	22.0	17.7	43.2	42.1
Totals, Mass	4,588	1,486,754	11.4	88.6	290,346	24.3	483,918	48.3	169,045	—115	—0.6	—43	......	1,317,709	290,461	28.3	483,961	58.0	324.1	63.3	24.3	105.5	48.3
NEW HAMPSHIRE—1880																							
Hillsboro	895	75,634	39.1	60.9	11,396	17.7	13,494	21.7	29,607	2,054	7.5	—2,361	—7.4	46,027	9,342	25.5	15,855	52.5	84.5	12.7	17.7	15.1	21.7
Rockingham	691	49,064	73.0	27.0	1,767	3.7	—1,058	—2.1	35,805	1,156	3.3	—1,673	—4.5	13,259	611	4.8	615	4.9	71.0	2.6	3.7	—1.5	—2.1
Totals, N. Hamp.	1,586	124,698	52.5	47.5	13,163	11.8	12,436	11.1	65,412	3,210	5.2	—4,034	—5.8	59,286	9,953	20.2	16,470	38.5	78.6	8.3	11.8	7.8	11.1
RHODE ISLAND—1880																							
Bristol	25	11,394	11.9	88.1	1,973	20.9	2,487	27.9	1,359	248	22.3	359	35.9	10,035	1,725	20.7	2,128	26.9	455.7	78.9	20.9	99.5	27.9
Kent	174	20,588	4.9	95.1	1,993	10.7	3,285	19.0	1,018	—115	—1.0	—216	—19.5	19,570	2,108	12.1	3,531	22.0	118.3	11.5	10.7	18.9	19.0
Providence	430	197,874	2.7	97.3	48,684	32.6	90,075	83.6	5,269	1,254	31.2	907	20.8	192,605	47,430	32.7	89,168	86.2	460.2	113.3	32.6	209.5	83.6
Totals, R. Isld.	629	229,856	3.3	96.7	52,650	29.7	95,847	71.5	7,646	1,387	22.1	1,020	15.4	222,210	51,263	30.0	94,827	74.4	365.4	83.7	29.7	152.4	71.5
Grand totals	7,344	1,885,164	13.4	86.6	361,497	23.7	601,778	46.9	254,236	3,693	1.4	—4,103	—1.6	1,631,928	357,804	28.1	605,881	59.0	256.7	49.3	23.7	81.9	46.9
CONNECTICUT—1890																							
Windham	500	45,158	19.5	80.5	1,302	3.0	10,879	31.7	8,797	—2,336	—20.9	—3,382	—27.8	36,361	3,638	11.1	14,261	64.5	90.3	9.2	11.3	26.9	42.4
Totals, Conn.	500	45,158	19.5	80.5	1,302	3.0	10,879	31.7	8,797	—2,336	—20.9	—3,382	—27.8	36,361	3,638	11.1	14,261	64.5	90.3	9.2	11.3	26.9	42.4
MASSACHUSETTS—1890																							
Bristol	567	186,465	8.1	91.9	47,425	34.1	92,671	98.8	15,017	—27	—0.2	—1,312	—8.0	171,448	47,452	38.3	93,983	121.3	328.9	84.7	34.1	163.5	98.8
Essex	497	299,995	6.6	93.4	55,460	22.7	134,384	81.4	19,922	—1,146	—5.4	—5,901	—22.9	280,073	56,606	25.3	140,285	100.4	603.6	111.6	22.7	270.4	81.4
Middlesex	837	431,167	7.8	92.2	113,337	35.7	214,813	99.3	33,489	—9,617	—22.3	—7,657	—18.6	397,678	122,954	44.7	222,470	127.0	515.1	135.4	35.7	258.2	100.5
Norfolk	410	118,950	11.1	88.9	22,443	23.3	9,000	8.2	13,193	—4,108	—23.7	2,580	24.3	105,757	26,551	33.5	6,420	6.5	290.1	54.7	23.3	29.0	11.4
Plymouth	675	92,700	24.7	75.3	18,682	25.2	27,932	43.1	22,938	—157	—0.7	1,208	5.6	69,762	18,839	37.0	26,724	62.1	137.3	27.7	25.2	41.4	43.1
Suffolk	46	484,780	.....	100.0	96,853	25.0	292,080	151.6	....	—3,306	......	—1,465	......	484,780	100,159	26.0	293,545	153.5	10,538.6	2,105.5	25.0	3,893.8	58.6
Worcester	1,556	280,787	14.6	85.4	53,890	23.8	121,128	75.9	40,955	—5,170	—11.2	—11,027	—21.2	239,832	59,060	32.7	132,155	122.7	180.4	34.6	23.8	77.8	75.9
Totals, Mass.	4,588	1,894,844	7.7	92.3	408,090	27.4	892,008	88.9	145,514	—23,531	—13.9	—23,574	—13.9	1,749,330	431,621	32.8	915,582	109.8	413.0	88.9	27.4	194.4	88.9
NEW HAMPSHIRE—1890																							
Hillsboro	895	93,247	26.0	74.0	17,613	23.3	31,107	50.1	24,289	—5,318	—17.9	—7,679	—24.0	68,958	22,931	49.8	38,756	128.5	104.2	19.7	23.3	34.8	50.1
Rockingham	691	49,650	60.8	39.2	586	1.2	—472	—0.9	30,193	—5,612	—15.7	—7,285	—19.4	19,457	6,198	46.7	6,813	53.9	71.9	0.9	1.2	—0.6	—0.9
Totals, N. Hamp.	1,586	142,897	38.1	61.9	18,199	14.6	30,635	27.3	54,482	—10,930	—16.7	—14,964	—21.5	88,415	29,129	49.1	45,599	106.5	90.1	11.5	14.6	19.3	27.3
RHODE ISLAND—1890																							
Bristol	25	11,428	12.8	87.2	34	0.3	2,521	28.3	1,461	102	7.5	461	46.1	9,967	—68	—0.7	2,060	26.0	457.1	1.4	0.3	100.9	28.3
Kent	174	26,754	3.0	97.0	6,166	29.9	9,451	54.6	798	—220	—2.2	—466	—36.9	25,956	6,386	32.6	9,917	61.8	153.7	35.4	29.9	54.3	54.6
Providence	430	255,123	2.1	97.9	57,249	28.9	147,324	136.7	5,431	162	3.1	1,069	24.5	249,692	57,087	29.6	146,255	141.4	593.3	133.1	28.9	342.6	136.7
Totals, R. Isld.	629	293,305	2.6	97.4	63,449	27.6	159,296	118.9	7,690	44	0.6	1,064	16.1	285,615	63,405	28.5	158,232	124.2	466.3	100.9	27.6	253.3	118.9
Grand totals	7,344	2,376,204	9.1	90.9	491,040	26.0	1,092,818	85.1	216,483	—36,753	—14.5	—40,856	—15.9	2,159,721	527,793	32.3	1,133,674	110.5	323.6	66.9	26.0	148.8	85.1

* In the states of Connecticut, Massachusetts, New Hampshire and Rhode Island, all "towns" having 2,500 or more inhabitants are classed as urban population; less than 2,500, as rural communities.

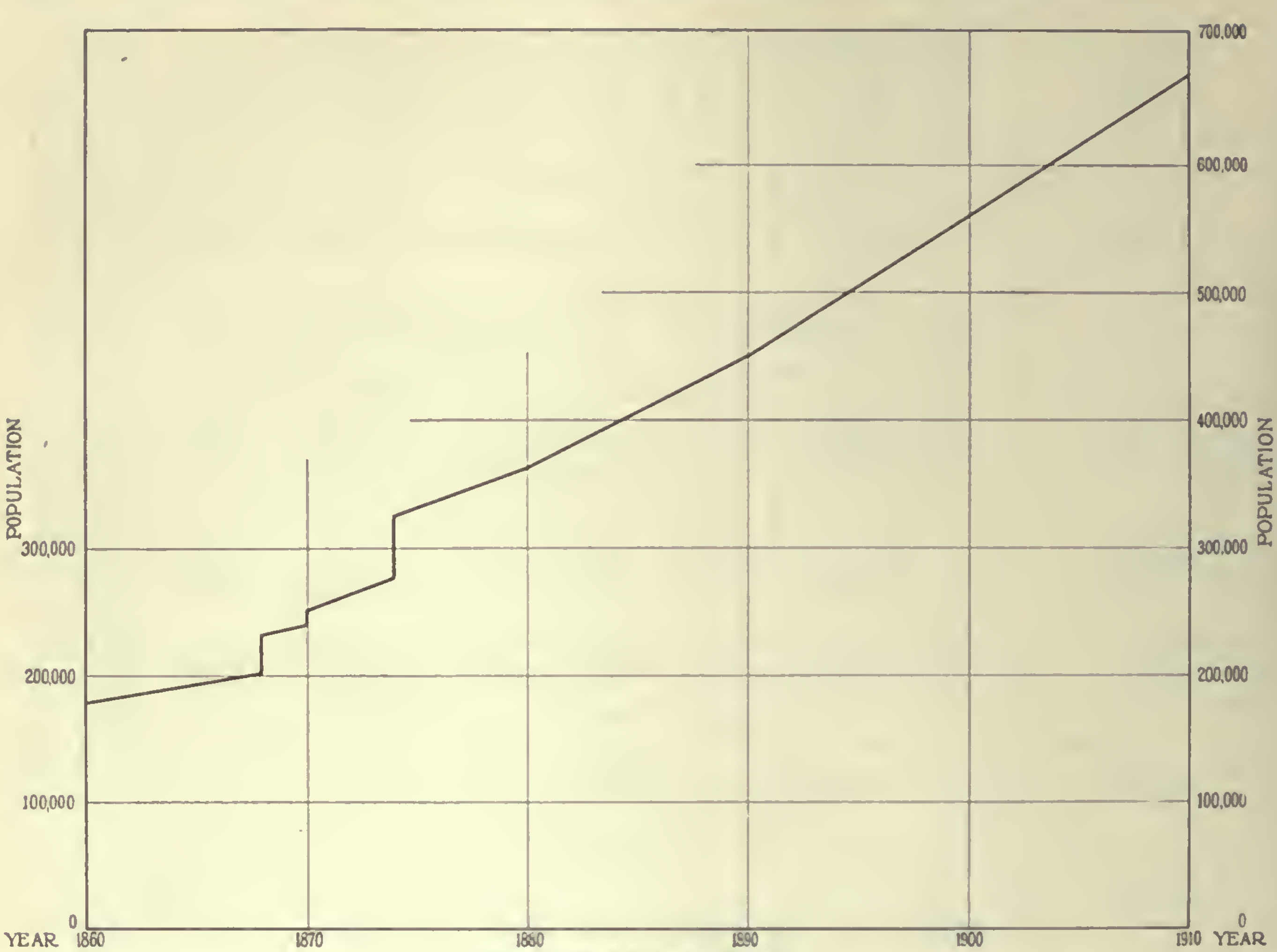
† Minus sign (—) denotes decrease.

TABLE CDLXVI (Concluded). STATISTICS OF POPULATION OF COUNTIES IN THE STATES OF CONNECTICUT, MASSACHUSETTS, NEW HAMPSHIRE, AND RHODE ISLAND, WITHIN 50 MILES OF BOSTON, AS SHOWN BY THE UNITED STATES CENSUS, DECADES ENDING 1860 TO 1910, INCLUSIVE

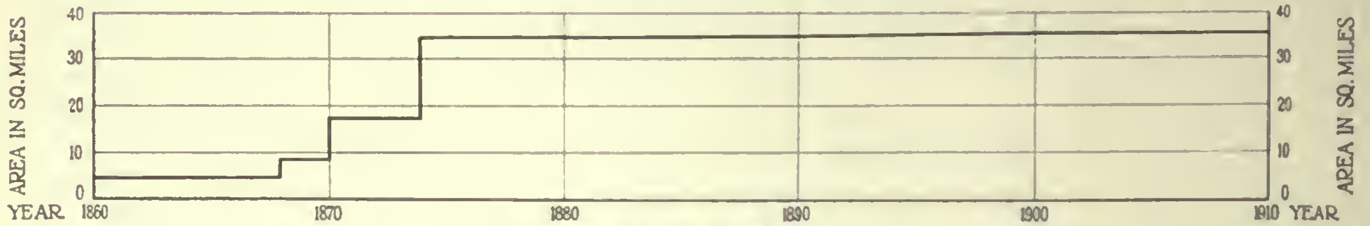
County	Area Sq. Miles	Population of County							Rural Population of County*					Population of Cities and Villages					Population per Square Mile				
		Total	Per Cent in Rural Communities	Per Cent in Urban Communities	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease			
					Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860	
					No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
CONNECTICUT—1900																							
Windham	500	46,861	24.1	75.9	1,703	3.8	12,582	36.7	11,278	2,481	28.2	—901	—7.4	35,583	—778	—2.1	13,483	61.0	93.7	3.4	3.8	30.3	47.8
Totals, Conn.	500	46,861	24.1	75.9	1,703	3.8	12,582	36.7	11,278	2,481	28.2	—901	—7.4	35,583	—778	—2.1	13,483	61.0	93.7	3.4	3.8	30.3	47.8
MASSACHUSETTS — 1900																							
Bristol	567	252,029	6.4	93.6	65,564	35.2	158,235	168.7	16,131	1,114	7.4	—198	—1.2	235,898	64,450	37.6	158,433	204.5	444.4	115.5	35.2	279.0	168.7
Essex	497	357,030	6.0	94.0	57,035	19.0	191,419	115.6	21,252	1,330	6.7	—4,571	—17.7	335,778	55,705	19.8	195,990	140.2	718.4	114.8	19.0	385.2	115.6
Middlesex	837	565,696	5.1	94.9	134,529	31.0	349,342	161.5	29,009	—4,480†	—13.4	—12,137	—29.5	536,687	139,009	34.9	361,479	206.3	675.8	160.7	31.0	418.9	163.1
Norfolk	410	151,539	7.6	92.4	32,589	27.4	41,589	37.8	11,513	—1,680	—12.8	900	8.4	140,026	34,269	32.4	40,689	41.0	369.6	79.5	27.4	109.1	41.9
Plymouth	675	113,985	21.2	78.8	21,285	23.0	49,217	76.0	24,152	1,214	5.3	2,422	11.1	89,833	20,071	28.7	46,795	108.7	168.8	31.5	23.0	72.9	76.0
Suffolk	46	611,417	.....	100.0	126,637	26.1	418,717	217.3	......	......	......	—1,465	.....	611,417	126,637	26.1	420,182	219.7	13,291.6	2,753.0	26.1	6,646.8	100.0
Worcester	1,556	346,958	13.7	86.3	66,171	23.6	187,299	117.3	47,423	6,468	15.8	—4,559	—8.8	299,535	59,703	24.8	191,858	178.2	222.9	42.5	23.6	120.3	117.3
Totals, Mass.	4,588	2,398,654	6.2	93.8	503,810	26.6	1,395,818	139.2	149,480	3,966	2.7	—19,608	—11.6	2,249,174	499,844	28.6	1,415,426	169.8	522.8	109.8	26.6	304.2	139.2
NEW HAMPSHIRE — 1900																							
Hillsboro	895	112,640	20.4	79.6	19,393	20.8	50,500	81.3	22,961	—1,328	—5.5	—9,007	—29.0	89,679	20,721	30.0	59,507	197.2	125.8	21.6	20.8	56.4	81.3
Rockingham	691	51,118	56.9	43.1	1,468	3.0	996	2.0	29,084	—1,109	—3.7	—8,394	—22.4	22,034	2,577	13.2	9,390	74.3	74.0	2.1	3.0	1.5	2.0
Totals, N. Hamp.	1,586	163,758	31.8	68.2	20,861	14.6	51,496	45.9	52,045	—2,437	—4.5	—17,401	—25.1	111,713	23,298	26.4	68,897	160.9	103.2	13.1	14.6	32.4	45.9
RHODE ISLAND — 1900																							
Bristol	25	13,144	8.6	91.4	1,716	15.0	4,237	47.6	1,135	—326	22.3	135	13.5	12,009	2,042	20.5	4,102	51.8	525.7	68.6	15.0	169.5	47.6
Kent	174	29,976	2.0	98.0	3,222	12.0	12,673	73.2	606	—192	—24.0	—658	—52.1	29,370	3,414	13.1	13,331	83.1	172.2	18.5	12.0	72.8	73.2
Providence	430	328,683	2.2	97.8	73,560	28.8	220,884	204.9	7,142	1,711	31.5	2,780	63.7	321,541	71,849	28.8	218,104	210.9	764.3	171.0	28.8	513.6	204.9
Totals, R. Isld.	629	371,803	2.4	97.6	78,498	26.8	237,794	177.5	8,883	1,193	15.5	2,257	34.1	362,920	77,305	27.1	235,537	184.9	591.1	124.8	26.8	378.1	177.5
Grand totals	7,344	2,981,076	7.4	92.6	604,872	25.4	1,697,690	132.3	221,686	5,203	2.4	—35,653	—13.9	2,759,390	599,669	27.8	1,733,343	168.9	405.9	82.3	25.4	231.1	132.3
CONNECTICUT — 1910																							
Windham	500	48,361	21.5	78.5	1,500	3.2	14,082	41.1	10,390	—888	—7.8	—1,789	—14.7	37,971	2,388	6.7	15,871	71.8	96.7	3.0	3.2	33.3	52.5
Totals, Conn.	500	48,361	21.5	78.5	1,500	3.2	14,082	41.1	10,390	—888	—7.8	—1,789	—14.7	37,971	2,388	6.7	15,871	71.8	96.7	3.0	3.2	33.3	52.5
MASSACHUSETTS — 1910																							
Bristol	567	318,573	4.6	95.4	66,544	26.4	224,779	239.7	14,498	—1,633	—10.1	—1,831	—11.2	304,075	68,177	28.8	226,610	292.5	561.8	117.4	26.4	396.4	239.7
Essex	497	436,477	5.0	95.0	79,447	22.3	270,866	163.6	21,890	638	3.0	—3,933	—15.2	414,587	78,809	23.5	274,799	196.6	878.2	159.8	22.3	545.0	163.6
Middlesex	832	669,915	4.5	95.5	104,219	18.4	453,561	209.6	30,433	1,424	4.9	—10,713	—26.0	639,482	102,795	19.2	464,274	265.0	805.2	129.4	19.1	548.3	213.4
Norfolk	410	187,506	7.2	92.8	35,967	23.7	77,556	70.5	13,570	2,057	17.8	2,957	27.9	173,936	33,910	24.2	74,599	75.1	457.3	87.7	23.7	196.8	75.5
Plymouth	675	144,337	18.9	81.1	30,352	26.6	79,569	122.9	27,311	3,159	13.1	5,581	25.7	117,026	27,193	30.2	73,988	171.9	213.8	45.0	26.6	117.9	122.9
Suffolk	51	731,388	.....	100.0	119,971	19.6	538,688	279.5	......	......	......	—1,465	.....	731,388	119,971	19.6	540,153	282.5	14,340.9	1,049.3	7.9	7,606.1	115.8
Worcester	1,550	399,657	11.5	88.5	52,699	15.2	239,998	150.3	45,921	—1,502	—3.1	—6,061	—11.7	353,736	54,201	18.1	246,059	228.5	256.8	33.9	15.2	154.2	150.3
Totals, Mass	4,588	2,887,853	5.3	94.7	489,199	20.4	1,885,017	188.0	153,623	4,143	2.8	—15,465	—9.1	2,734,230	485,056	21.5	1,900,482	227.9	629.4	106.6	20.4	410.8	188.0
NEW HAMPSHIRE — 1910																							
Hillsboro	895	126,072	18.6	81.4	13,432	11.9	63,932	102.9	23,486	525	2.3	—8,482	—27.3	102,586	12,907	14.4	72,414	240.0	140.9	15.1	11.9	71.5	102.9
Rockingham	691	52,188	52.8	47.2	1,070	2.1	2,066	4.1	27,551	—1,533	—5.3	—9,927	—26.5	24,637	2,603	11.8	11,993	94.9	75.5	1.5	2.1	3.0	4.1
Totals, N. Hamp.	1,586	178,260	28.6	71.4	14,502	8.9	65,998	58.8	51,037	—1,008	—1.9	—18,409	—26.5	127,223	15,610	13.9	84,407	197.1	112.4	9.2	8.9	41.6	58.8
RHODE ISLAND — 1910																							
Bristol	25	17,602	13.9	86.1	4,458	33.9	8,695	97.6	2,452	1,317	116.0	1,452	145.2	15,150	3,141	26.1	7,243	91.6	704.1	178.4	33.9	347.9	97.6
Kent	174	36,378	1.3	98.7	6,402	21.4	19,075	110.2	481	—125	—20.6	—783	—61.9	35,897	6,527	22.2	19,858	123.8	209.1	36.9	21.4	109.7	110.2
Providence	430	424,353	0.6	99.4	95,670	29.1	316,554	293.7	2,528	—4,614	—64.6	—1,834	—42.0	421,825	100,284	31.2	318,388	307.8	986.9	222.6	29.1	736.2	293.7
Totals, R. Isld.	629	478,333	1.1	98.9	106,530	28.6	344,324	256.9	5,461	—3,422	—38.5	—1,165	—17.6	472,872	109,952	30.3	345,489	271.2	760.5	169.4	28.6	347.5	256.9
Grand totals	7,344	3,592,807	6.1	93.9	611,731	20.5	2,309,421	179.9	220,511	1,175	—0.5	—36,828	—14.3	3,372,296	612,906	22.2	2,346,249	228.7	489.2	83.3	20.5	314.4	179.9

* In the states of Connecticut, Massachusetts, New Hampshire and Rhode Island, all "towns" having 2,500 or more inhabitants are classed as urban population; less than 2,500 as rural communities.

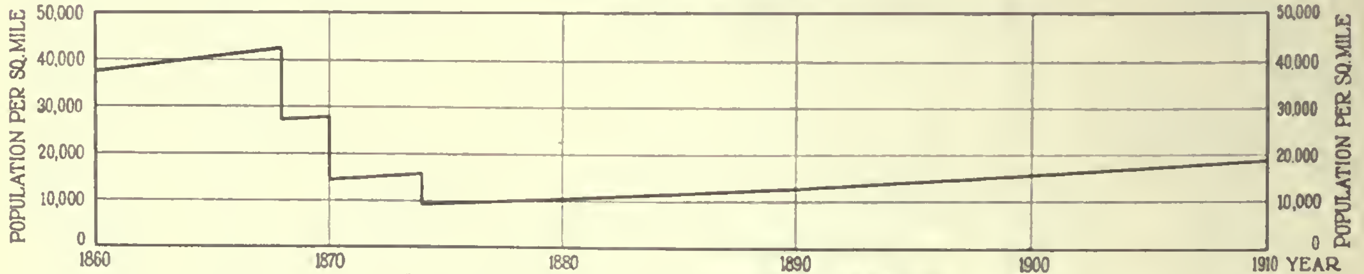
† Minus sign (—) denotes decrease.



POPULATION OF BOSTON 1860-1910



AREA OF BOSTON 1860-1910



POPULATION PER SQUARE MILE OF BOSTON 1860-1910

FIG. 705. CHANGES IN POPULATION AND AREA OF THE CITY OF BOSTON, BASED ON UNITED STATES CENSUS AND MUNICIPAL REPORTS, 1860-1910

TABLE CDLXVII. INCREASES IN THE POPULATION OF PHILADELPHIA AND OF THE INDUSTRIAL ZONE OUTSIDE OF PHILADELPHIA, 1860-1910

Decade	Increase in Total Population of Zone		Increase in the Population of the City of Philadelphia		Increase in the Population of the Industrial Zone Outside of the City of Philadelphia					
							Increase in Cities and Villages		Increase in Rural Districts	
	Total Increase	Per Cent of Increase	Total Increase	Per Cent of Increase	Total Increase	Per Cent of Increase in Total Population	Total Increase	Per Cent of Total Increase Outside of the City of Philadelphia	Total Increase	Per Cent of Total Increase Outside of the City of Philadelphia
1	2	3	4	5	6	7	8	9	10	11
1860–1870	255,464	16.8	108,493	19.2	146,971	57.53	111,606	75.94	35,365	24.06
1870–1880	347,685	19.5	173,148	25.7	174,537	50.20	157,011	89.96	17,526	10.04
1880–1890	413,701	19.5	199,794	23.6	213,907	51.71	215,974	100.97	—2,067*	—0.97
1890–1900	466,410	18.4	246,733	23.6	219,677	47.10	236,062	107.46	—16,385	—7.46
1900–1910	588,042	19.6	255,311	19.7	332,731	56.58	307,787	92.50	24,944	7.50
Totals	2,071,302	136.0	983,479	173.9	1,087,823	52.52	1,028,440	94.54	59,383	5.46

* Minus sign (—) denotes decrease.

701.33 Comparative Population of the Industrial Zones of Chicago, New York, Boston and Philadelphia, of the Largest City in Each Zone and of the Zone Outside of the Largest City: Table CDLXXII presents numerical and percentage statistics for the years 1890, 1900 and 1910, respectively, of the population of the four largest industrial zones, of the largest city in each zone and of the zone outside of the largest city; also, numerical and percentage statistics of the population living in cities and villages and in the rural districts. This table is supplemented by a series of charts, presented as figs. 707 to 712, inclusive, showing changes in population of the eight largest cities of the United States, changes in the urban and the rural population of counties located within 50 miles of New York, Chicago, Philadelphia and Boston, and changes in the population and area of the cities of Baltimore, Cleveland, Pittsburgh and St. Louis, for the years 1860 to 1910, inclusive.

TABLE CDLXVIII. COMPARATIVE INCREASES IN THE POPULATION OF CITIES AND VILLAGES LYING WITHIN EACH INDUSTRIAL ZONE, EXCLUSIVE OF THE LARGEST CITY OF EACH ZONE, 1860-1910

Decade	New York Zone		Philadelphia Zone		Boston Zone		Chicago Zone	
	Total Increase	Per Cent of Total Increase of Population Outside of the City of New York	Total Increase	Per Cent of Total Increase of Population Outside of the City of Philadelphia	Total Increase	Per Cent of Total Increase of Population Outside of the City of Boston	Total Increase	Per Cent of Total Increase of Population Outside of the City of Chicago
1	2	3	4	5	6	7	8	9
1860–1870	418,007	96.08	111,606	75.94	175,391	104.65	18,166	26.63
1870–1880	434,463	107.30	157,011	89.96	245,491	98.52	85,675	98.88
1880–1890	627,404	96.21	215,974	100.97	442,155	109.07	70,135	159.20
1890–1900	—393,162	—81.62	236,062	107.46	487,254	98.94	123,240	99.31
1900–1910	723,523	91.03	307,787	92.50	503,213	100.23	186,428	99.33
Totals	1,810,235	100.27	1,028,440	94.54	1,853,504	102.03	483,644	94.70

TABLE CDLXIX. COMPARATIVE POPULATION AND DENSITY OF THE FOUR LARGEST INDUSTRIAL ZONES
1860-1910

Year	New York Zone		Philadelphia Zone		Boston Zone		Chicago Zone	
	Population		Population		Population		Population	
	Total	Per Square Mile	Total	Per Square Mile	Total	Per Square Mile	Total	Per Square Mile
1	2	3	4	5	6	7	8	9
1860	1,990,477	260.4	1,523,174	142.4	1,283,386	174.8	340,626	51.0
1870	2,554,155	334.1	1,778,638	166.3	1,523,667	207.5	598,563	89.6
1880	3,223,064	421.6	2,126,323	198.8	1,885,164	256.7	889,415	133.1
1890	4,184,216	547.4	2,540,024	237.4	2,376,204	323.6	1,530,135	229.0
1900	5,624,443	735.8	3,006,434	281.0	2,981,076	405.9	2,252,960	337.2
1910	7,748,963	1013.7	3,594,476	336.0	3,592,807	489.2	2,927,357	438.2

TABLE CDLXX. COMPARATIVE INCREASES IN THE URBAN POPULATION OF THE FOUR LARGEST INDUSTRIAL ZONES
1860–1910

Decade	Increase in Urban Population of all Zones		Increase for the New York Zone		Increase for the Chicago Zone		Increase for the Philadelphia Zone		Increase for the Boston Zone	
	Total	Per Cent of Increase	Total	Per Cent of Increase in Urban Population of all Zones	Total	Per Cent of Increase in Urban Population of all Zones	Total	Per Cent of Increase in Urban Population of all Zones	Total	Per Cent of Increase in Urban Population of all Zones
1	2	3	4	5	6	7	8	9	10	11
1860–1870	1,222,689	36.98	546,630	44.71	207,883	17.00	220,099	18.00	248,077	20.29
1870–1880	1,676,316	37.01	698,470	41.67	289,883	17.29	330,159	19.70	357,804	21.34
1880–1890	2,546,767	41.04	936,406	36.77	666,800	26.18	415,768	16.33	527,793	20.72
1890–1900	3,333,168	38.08	1,528,739	45.86	721,965	21.66	482,795	14.49	599,669	17.99
1900–1910	3,902,344	32.29	2,053,204	52.61	673,136	17.25	563,098	14.43	612,906	15.71
Totals	12,681,284	383.57	5,763,449	45.45	2,559,667	20.18	2,011,919	15.87	2,346,249	18.50

TABLE CDLXXI. INCREASES IN THE POPULATION OF THE FOUR LARGEST INDUSTRIAL ZONES DURING THE 50 YEARS
1860–1910

Zone	Increase in Total Population		Increase in Population of Largest City		Increase in Population of Industrial Zone Outside of the Largest City					
							Included in Cities and Villages		Included in Rural Districts	
	Total Increase	Per Cent of Increase	Total Increase	Per Cent of Increase in Total Population	Total Increase	Per Cent of Increase in Total Population	Total Increase	Per Cent of Increase Outside of Largest City	Total Increase	Per Cent of Increase Outside of Largest City
1	2	3	4	5	6	7	8	9	10	11
New York	5,758,486	289.30	3,953,214	68.65	1,805,272	31.35	1,810,235	100.27	—4,963*	—0.27
Philadelphia	2,071,302	135.99	983,479	47.48	1,087,823	52.52	1,028,440	94.54	59,383	5.46
Boston	2,309,421	179.95	492,745	21.34	1,816,676	78.66	1,853,504	102.03	—36,828	—2.03
Chicago	**2,586,731**	**759 40**	**2,076,023**	**80 26**	**510,708**	**19 74**	**483,644**	**94.70**	**27,064**	**5 30**
Totals	12,725,940	247.70	7,505,461	58.98	5,220,479	41.02	5,175,823	99.14	44,656	0.86

* Minus sign (—) denotes decrease.

TABLE CDLXXII. COMPARATIVE POPULATION OF THE FOUR LARGEST INDUSTRIAL ZONES, OF THE LARGEST CITY IN EACH ZONE AND OF THE ZONE OUTSIDE OF THE LARGEST CITY, IN 1890, 1900 AND 1910

Zone	Total Population	Population of Largest City		Population of Industrial Zone Outside of Largest City					
						Population Living in Cities and Villages		Population Living in Rural Districts	
		Total Population	Per Cent of Total Population of Zone	Total Population	Per Cent of Total Population of Zone	Total	Per Cent of Total Population Living Outside of Largest City	Total	Per Cent of Total Population Living Outside of Largest City
1	2	3	4	5	6	7	8	9	10
				1890					
New York	4,184,216	1,515,301	36.21	2,668,915	63.79	2,007,623	75.22	661,292	24.78
Philadelphia	2,540,024	1,046,964	41.22	1,493,060	58.78	707,789	47.41	785,271	52.59
Boston	2,376,204	448,477	18.87	1,927,727	81.13	1,711,244	88.77	216,483	11.23
Chicago	**1,530,135**	**1,099,850**	**71.88**	**430,285**	**28.12**	**214,679**	**49 89**	**215,606**	**50.11**
Totals	10,630,579	4,110,592	38.67	6,519,987	61.33	4,641,335	71.19	1,878,652	28.81
				1900					
New York	5,624,443	3,437,202	61.11	2,187,241	38.89	1,614,461	73.81	572,780	26.19
Philadelphia	3,006,434	1,293,697	43.03	1,712,737	56.97	943,851	55.11	768,886	44.89
Boston	2,981,076	560,892	18.82	2,420,184	81.18	2,198,498	90.84	221,686	9.16
Chicago	**2,252,960**	**1,698,575**	**75 39**	**554,385**	**24.61**	**337,919**	**60.95**	**216,466**	**39.05**
Totals	13,864,913	6,990,366	50.42	6,874,547	49.58	5,094,729	74.11	1,779,818	25.89
				1910					
New York	7,748,963	4,766,883	61.52	2,982,080	38.48	2,337,984	78.40	644,096	21.60
Philadelphia	3,594,476	1,549,008	43.09	2,045,468	56.91	1,251,638	61.19	793,830	38.81
Boston	3,592,807	670,585	18.66	2,922,222	81.34	2,701,711	92.45	220,511	7.55
Chicago	**2,927,357**	**2,165,283**	**74 65**	**742,074**	**25.35**	**524,347**	**70.66**	**217,727**	**29.34**
Totals	17,863,603	9,171,759	51.34	8,691,844	48.66	6,815,680	78.41	1,876,164	21.59

TABLE CDLXXIII. STATISTICS OF POPULATION OF COUNTIES IN THE STATES OF DELAWARE, MARYLAND, NEW JERSEY AND PENNSYLVANIA WITHIN 50 MILES OF PHILADELPHIA, AS SHOWN BY THE UNITED STATES CENSUS, DECADES ENDING 1860 TO 1910, INCLUSIVE

County	Area Sq. Miles	Population of County							Rural Population of County					Population of Cities and Villages					Population per Square Mile				
		Total	Per Cent in Rural Communities	Per Cent in Urban Communities	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease			
					Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860	
					No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
United States Census, Decade Ending 1860																							
New Castle... Del.	435	54,797	49.9	50.1	12,017	28.1	....	....	27,333	....	....	....	....	27,464	....	....	....	....	126.0	....	....	....	....
Cecil.... Md	377	23,862	100.0	....	4,923	26.0	....	....	23,862	....	....	....	....	....	....	....	....	....	63.3	....	....	....	....
Atlantic N. J	569	11,786	87.5	12.5	2,825	31.5	....	....	10,310	....	....	....	....	1,476	....	....	....	....	20.7	....	....	....	....
Burlington "	871	49,730	87.1	12.9	6,527	15.1	....	....	43,336	....	....	....	....	6,394	....	....	....	....	57.1	....	....	....	....
Camden.. "	260	34,457	58.3	41.7	9,035	35.5	....	....	20,099	....	....	....	....	14,358	....	....	....	....	132.5	....	....	....	....
Cumberland "	500	22,605	66.7	33.3	5,416	31.5	....	....	15,078	....	....	....	....	7,527	....	....	....	....	45.2	....	....	....	....
Gloucester "	294	18,444	91.7	8.3	3,789	25.8	....	....	16,910	....	....	....	....	1,534	....	....	....	....	62.7	....	....	....	....
Hunterdon "	437	33,654	88.5	11.5	4,664	16.1	....	....	29,781	....	....	....	....	3,873	....	....	....	....	77.0	....	....	....	....
Mercer... "	226	37,419	51.4	48.6	9,427	33.7	....	....	19,221	....	....	....	....	18,198	....	....	....	....	165.5	....	....	....	....
Middlesex. "	312	34,812	61.1	38.9	6,177	21.6	....	....	21,254	....	....	....	....	13,558	....	....	....	....	111.5	....	....	....	....
Monmouth "	479	39,346	100.0	....	9,033	29.8	....	....	39,346	....	....	....	....	....	....	....	....	....	82.1	....	....	....	....
Ocean..... "	581	11,176	100.0	....	1,144	11.4	....	....	11,176	....	....	....	....	....	....	....	....	....	19.2	....	....	....	....
Salem..... "	343	22,458	77.6	22.4	2,991	15.4	....	....	17,418	....	....	....	....	5,040	....	....	....	....	65.5	....	....	....	....
Somerset . "	305	22,057	100.0	....	2,365	12.0	....	....	22,057	....	....	....	....	....	....	....	....	....	72.3	....	....	....	....
Berks.. Penn.	865	93,818	71.8	28.2	16,689	21.6	....	....	67,331	....	....	....	....	26,487	....	....	....	....	108.4	....	....	....	....
Bucks.. "	608	63,578	87.7	12.3	7,487	13.3	....	....	55,727	....	....	....	....	7,851	....	....	....	....	104.5	....	....	....	....
Chester "	777	74,578	84.2	15.8	8,140	12.2	....	....	62,808	....	....	....	....	11,770	....	....	....	....	96.0	....	....	....	....
Delaware "	185	30,597	74.5	25.5	5,918	23.9	....	....	22,789	....	....	....	....	7,808	....	....	....	....	165.3	....	....	....	....
Lancaster "	941	116,314	74.1	25.9	17,370	17.6	....	....	86,241	....	....	....	....	30,073	....	....	....	....	123.6	....	....	....	....
Lehigh.. "	344	43,753	77.2	22.8	11,274	34.7	....	....	33,796	....	....	....	....	9,957	....	....	....	....	127.1	....	....	....	....
Montgomery "	484	70,500	80.2	19.2	12,209	20.9	....	....	56,520	....	....	....	....	13,980	....	....	....	....	145.6	....	....	....	....
Northampton "	372	47,904	66.9	33.1	7,669	19.1	....	....	32,054	....	....	....	....	15,850	....	....	....	....	128.8	....	....	....	....
Philadelphia "	133	565,529	....	100.0	156,767	38.4	....	....	....	....	....	....	....	565,529	....	....	....	....	4,252.1	....	....	....	....
Totals, Del.	435	54,797	49.9	50.1	12,017	28.1	....	....	27,333	....	....	....	....	27,464	....	....	....	....	126.0	....	....	....	....
Totals, Md.	377	23,862	100.0	....	4,923	26.0	....	....	23,862	....	....	....	....	....	....	....	....	....	63.3	....	....	....	....
Totals, N. J.	5,177	337,944	78.7	21.3	63,393	23.1	....	....	265,986	....	....	....	....	71,958	....	....	....	....	65.3	....	....	....	....
Totals, Penn.	4,709	1,106,571	37.7	62.3	243,523	28.2	....	....	417,266	....	....	....	....	689,305	....	....	....	....	234.9	....	....	....	....
Grand totals	10,698	1,523,174	48.2	51.8	323,856	27.0	....	....	734,447	....	....	....	....	788,727	....	....	....	....	142.3	....	....	....	....
United States Census, Decade Ending 1870																							
New Castle... Del.	435	63,515	41.2	58.8	8,718	15.9	8,718	15.9	26,146	—1,187*	—4.3	—1,187	—4.3	37,369	9,905	36.0	9,905	36.0	146.0	20.0	15.9	20.0	15.9
Cecil..... Md.	377	25,874	74.2	25.8	2,012	8.4	2,012	8.4	19,200	—4,662	—19.5	—4,662	—19.5	6,674	6,674	....	6,674	....	68.6	5.3	8.4	5.3	8.4
Atlantic N. J.	569	14,093	73.3	26.7	2,307	19.5	2,307	19.5	10,335	25	0.2	25	0.2	3,758	2,282	15.5	2,282	15.5	24.7	4.0	19.5	4.0	19.5
Burlington "	871	53,639	85.0	15.0	3,909	7.9	3,909	7.9	45,607	2,271	5.2	2,271	5.2	8,032	1,638	2.5	4,638	2.5	61.5	4.4	7.9	4.4	7.9
Camden.. "	260	46,192	45.8	54.2	11,735	34.1	11,735	34.1	21,145	1,046	5.2	1,046	5.2	25,047	10,689	74.4	10,689	74.4	177.6	45.1	34.1	45.1	34.1
Cumberland. "	500	34,665	62.7	37.3	12,060	53.4	12,060	53.4	21,734	6,656	44.1	6,656	44.1	12,931	5,404	71.8	5,404	71.8	69.3	24.1	53.4	24.1	53.4
Gloucester "	294	21,562	90.9	9.1	3,118	16.9	3,118	16.9	19,597	2,687	15.9	2,687	15.9	1,965	431	2.8	431	2.8	73.3	10.6	16.9	10.6	16.9
Hunterdon "	437	36,963	83.3	16.7	3,309	9.8	3,309	9.8	30,797	1,016	3.4	1,016	3.4	6,166	2,293	59.2	2,293	59.2	84.6	7.6	9.8	7.6	9.8
Mercer... "	226	46,386	41.8	58.2	8,967	24.0	8,967	24.0	19,367	146	0.8	146	0.8	27,019	8,821	48.5	8,821	48.5	205.2	39.7	24.0	39.7	24.0
Middlesex "	312	45,029	60.2	39.8	10,217	29.3	10,217	29.3	27,110	5,856	27.6	5,856	27.6	17,919	4,361	32.2	4,361	32.2	144.3	32.8	29.3	32.8	29.3
Monmouth "	479	46,195	100.0	....	6,849	17.4	6,849	17.4	46,195	6,849	17.4	6,849	17.4	....	....	....	....	....	96.4	14.3	17.4	14.3	17.4
Ocean.... "	581	13,628	100.0	....	2,452	21.9	2,452	21.9	13,628	2,452	2.2	2,452	2.2	....	....	....	....	....	23.4	4.3	21.9	4.3	21.9
Salem.... "	343	23,940	71.5	28.5	1,482	6.6	1,482	6.6	17,124	—294	—1.7	—294	—1.7	6,816	1,776	35.2	1,776	35.2	69.8	4.3	6.6	4.3	6.6
Somerset. "	305	23,510	83.8	16.2	1,453	6.6	1,453	6.6	19,709	—2,348	—10.6	—2,348	—10.6	3,801	3,801	....	3,801	....	77.1	4.8	6.6	4.8	6.6
Berks.. Penn.	865	106,701	64.4	35.6	12,883	13.7	12,883	13.7	68,748	1,417	2.1	1,417	2.1	37,953	11,466	43.3	11,466	43.3	123.3	14.9	13.7	14.9	13.7
Bucks.. "	608	64,336	86.6	13.4	758	1.2	758	1.2	55,706	—21	....	—21	....	8,630	779	9.9	779	9.9	105.8	1.3	1.2	1.3	1.2
Chester. "	777	77,805	79.0	21.0	3,227	4.3	3,227	4.3	61,478	—1,330	—2.1	—1,330	—2.1	16,327	4,557	38.7	4,557	38.7	100.1	4.1	4.3	4.1	4.3
Delaware "	185	39,403	63.7	36.3	8,806	28.8	8,806	28.8	25,085	2,296	10.1	2,296	10.1	14,318	6,510	83.4	6,510	83.4	212.9	47.6	28.8	47.6	28.8
Lancaster "	941	121,340	71.1	28.9	5,026	4.3	5,026	4.3	86,261	20	....	20	....	35,079	5,006	16.6	5,006	16.6	128.9	5.3	4.3	5.3	4.3
Lehigh.. "	344	56,796	65.8	34.2	13,043	29.8	13,043	29.8	37,346	3,550	10.5	3,550	10.5	19,450	9,493	95.3	9,493	95.3	165.1	38.0	29.8	38.0	29.8
Montgomery "	484	81,612	75.6	24.4	11,112	15.8	11,112	15.8	61,678	5,158	9.1	5,158	9.1	19,934	5,954	42.6	5,954	42.6	168.6	23.0	15.8	23.0	15.8
Northampton "	372	61,432	58.3	41.7	13,528	28.2	13,528	28.2	35,816	3,762	11.7	3,762	11.7	25,616	9,766	61.6	9,766	61.6	165.1	36.3	28.2	36.3	28.2
Philadelphia "	133	674,022	....	100.0	108,493	19.2	108,493	19.2	....	....	....	....	....	674,022	108,493	19.2	108,493	19.2	5,067.8	815.7	19.2	815.7	19.2
Totals, Del.	435	63,515	41.2	58.8	8,718	15.9	8,718	15.9	26,146	—1,187	—4.3	—1,187	—4.3	37,369	9,905	36.0	9,905	36.0	146.0	20.0	15.9	20.0	15.9
Totals, Md.	377	25,874	74.2	25.8	2,012	8.4	2,012	8.4	19,200	—4,662	—19.5	—4,662	—19.5	6,674	6,674	....	6,674	....	68.6	5.3	8.4	5.3	8.4
Totals, N. J.	5,177	405,802	72.0	28.0	67,858	20.1	67,858	20.1	292,348	26,362	9.9	26,362	9.9	113,454	41,496	57.7	41,496	57.7	78.4	13.1	20.1	13.1	20.1
Totals, Penn.	4,709	1,283,447	33.7	66.3	176,876	16.0	176,876	16.0	432,118	14,852	3.6	14,852	3.0	851,329	162,024	23.5	162,024	23.5	272.6	37.6	16.0	37.6	16.0
Grand totals	10,698	1,778,638	43.3	56.7	255,464	16.8	255,464	16.8	769,812	35,365	4.8	35,365	4.8	1,008,826	220,099	27.9	220,099	27.9	166.2	23.9	16.8	23.9	16.8

* Minus sign (—) denotes decrease.

TABLE CDLXXIII (Continued). STATISTICS OF POPULATION OF COUNTIES IN THE STATES OF DELAWARE, MARYLAND, NEW JERSEY AND PENNSYLVANIA WITHIN 50 MILES OF PHILADELPHIA, AS SHOWN BY THE UNITED STATES CENSUS. DECADES ENDING 1860 TO 1910, INCLUSIVE

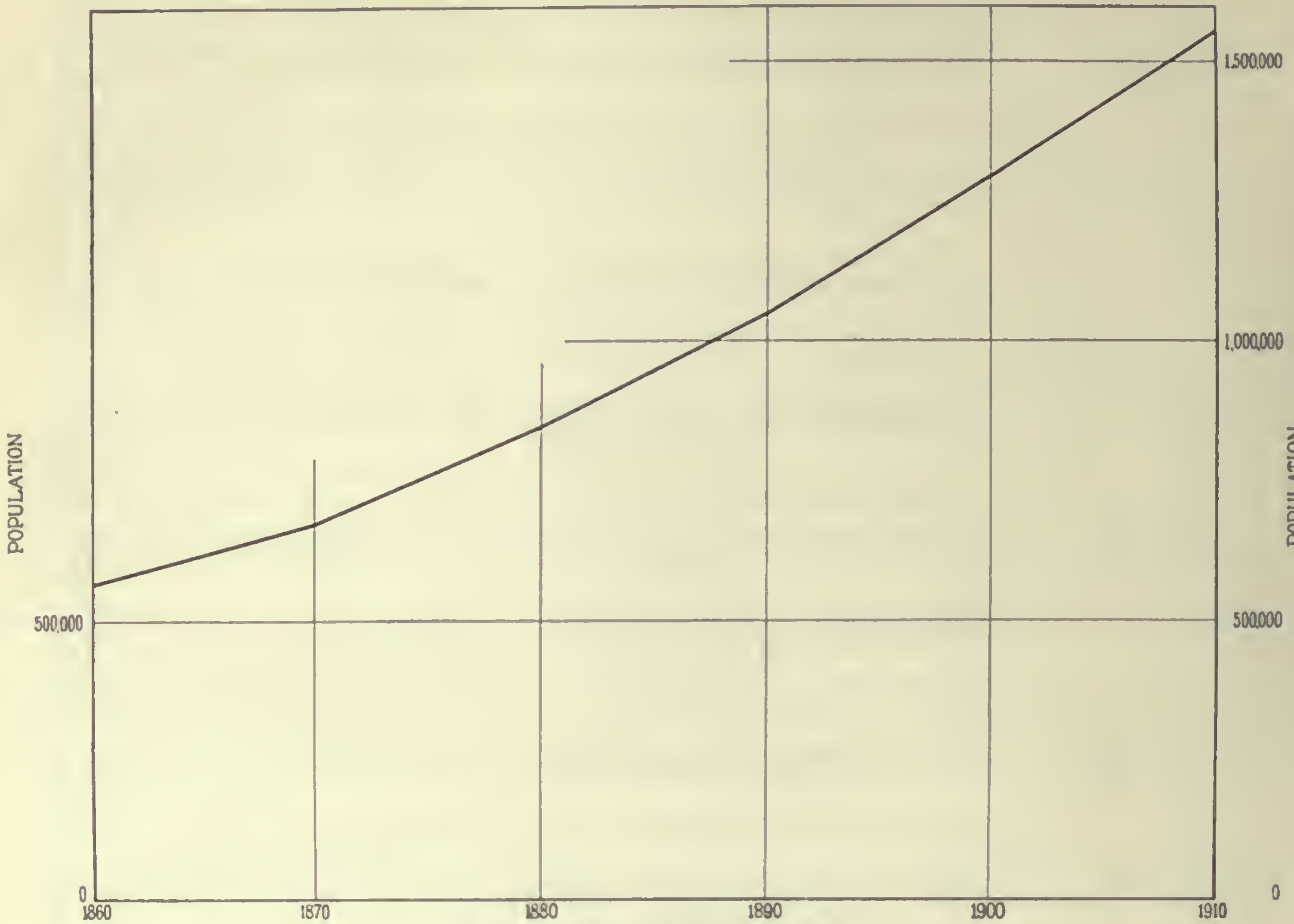
County	Area Sq. Miles	Population of County								Rural Population of County					Population of Cities and Villages					Population per Square Mile				
		Total	Per Cent in Rural Communities	Per Cent in Urban Communities	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease			
					Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860	
					No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
United States Census, Decade Ending 1880																							
New Castle Del.	435	77,716	37.3	62.7	14,201	22.4	22,919	41.6	28,966	2,820	1.1	1,633	6.0	48,750	11,381	30.5	21,286	77.5	178.6	32.6	22.4	52.6	41.6
Cecil Md.	377	27,108	72.1	27.9	1,234	4.8	3,246	13.6	19,551	351	1.8	—4,311	—18.1	7,557	883	1.3	7,557	..	71.9	3.3	4.8	8.6	13.6
Atlantic, N.J.	569	18,704	51.6	45.4	4,611	32.7	6,918	58.6	10,219	—416	—1.1	—91	—0.9	8,485	4,727	125.7	7,009	474.9	32.8	8.1	32.7	12.1	58.6
Burlington "	871	55,402	75.6	24.4	1,763	3.3	5,672	11.4	41,910	—3,697	—8.1	—1,426	—3.3	13,492	5,460	67.9	7,098	111.0	63.6	2.1	3.3	6.5	11.4
Camden "	222	62,942	22.3	77.7	16,750	36.3	28,485	82.7	14,017	—7,128	—33.7	—6,082	—30.3	48,925	23,878	95.3	34,567	240.8	283.5	105.9	59.6	154.0	114.0
Cumberland "	500	37,687	49.8	50.2	3,022	8.7	15,082	66.7	18,786	—2,948	—13.6	3,708	24.6	18,901	5,970	46.2	11,374	151.1	75.4	6.1	8.7	30.2	66.7
Gloucester "	332	25,886	84.9	15.1	4,324	20.0	7,442	40.3	21,989	2,392	12.2	5,079	30.0	3,897	1,932	98.3	2,363	154.0	78.0	4.7	6.4	15.3	24.4
Hunterdon "	437	38,570	81.9	18.1	1,607	4.3	4,916	14.6	31,597	800	2.6	1,816	6.1	6,973	807	1.3	3,100	80.0	88.2	3.6	4.3	11.2	14.6
Mercer "	226	58,061	30.0	70.0	11,675	25.2	20,642	55.2	17,427	—1,940	—10.0	—1,791	—9.3	40,634	13,615	50.4	22,436	123.3	256.9	51.7	25.2	94.4	55.2
Middlesex "	312	52,286	53.0	47.0	7,257	16.1	17,474	50.2	27,733	623	2.3	6,479	30.5	24,553	6,634	37.0	10,995	81.1	167.5	23.2	16.1	56.0	50.2
Monmouth "	479	55,538	81.3	18.7	9,313	20.2	16,192	41.2	45,152	—1,043	—2.3	5,806	14.8	10,386	10,386	...	10,386	.	115.9	19.5	20.2	33.8	41.2
Ocean "	581	14,455	99.8	0.2	827	6.0	3,278	29.3	14,421	793	5.8	3,245	29.0	34	34	.....	34	.	24.8	1.4	6.0	5.6	29.3
Salem "	313	24,579	76.0	21.0	639	2.7	2,121	9.4	18,688	1,564	9.1	1,270	7.3	5,891	—925	—13.5	851	16.9	74.6	1.8	2.7	6.1	9.4
Somerset "	305	27,162	73.5	26.5	3,652	15.5	5,105	23.1	19,974	265	1.3	—2,083	—9.4	7,188	3,387	89.4	7,188		89.0	11.9	15.4	16.7	23.1
Berks Penn.	865	122,597	57.5	42.5	15,896	14.9	28,779	30.7	70,488	1,740	2.5	3,457	4.7	52,109	14,456	37.3	25,622	96.7	141.7	18.4	14.9	33.3	30.7
Bucks "	608	68,656	79.7	20.3	1,320	6.7	5,078	8.0	54,699	—1,007	—1.8	—1,028	—1.8	13,957	5,327	61.7	6,106	77.8	112.9	7.4	6.7	8.4	8.0
Chester "	777	83,481	72.3	27.7	5,676	7.3	8,903	11.9	60,369	—1,409	—1.8	—2,439	—3.9	23,112	6,785	41.6	11,312	96.4	107.4	7.3	7.3	11.4	11.9
Delaware "	185	56,101	55.5	44.5	16,698	42.4	25,504	83.4	31,133	6,048	24.1	8,344	36.6	24,968	10,650	74.4	17,160	219.8	303.2	90.3	42.4	137.9	83.4
Lancaster "	941	139,417	68.7	31.3	18,107	14.9	23,133	19.9	95,853	9,592	11.1	9,612	11.1	43,501	8,515	24.3	13,521	45.0	148.2	19.3	14.9	24.6	19.9
Lehigh "	344	65,969	61.4	38.6	9,173	16.1	22,216	50.8	40,493	3,147	8.4	6,697	19.8	25,476	6,026	30.9	15,519	155.9	191.7	26.6	16.1	64.6	50.8
Montgomery "	484	96,494	68.8	31.2	14,881	18.2	25,994	36.9	66,358	4,680	7.6	9,838	17.4	30,136	10,202	51.2	16,156	115.6	199.3	30.7	18.2	53.7	36.9
Northampton "	372	70,312	53.4	46.6	8,880	14.5	22,408	46.8	37,515	1,609	4.7	5,461	17.0	32,797	7,181	28.0	16,947	106.9	189.0	23.9	14.5	60.2	46.8
Philadelphia "	133	847,170		100.0	173,148	25.7	281,641	49.8		..	.		......	847,170	173,148	25.7	281,641	49.8	6,369.7	1,301.9	25.7	2,117.6	49.8
Totals, Del.	435	77,716	37.3	62.7	14,201	22.4	22,919	41.6	28,966	2,820	1.1	1,633	6.0	48,750	11,381	30.5	21,286	77.5	178.6	32.6	22.4	52.6	41.6
Totals, Md.	377	27,108	72.1	27.9	1,234	4.8	3,246	13.6	19,551	351	1.8	—4,311	—18.1	7,557	883	1.3	7,557	....	71.9	3.3	4.8	8.6	13.6
Totals, N. J.	5,177	471,272	59.8	40.2	65,470	16.1	133,328	39.5	281,913	—10,435	—3.6	15,927	6.0	189,359	75,905	66.9	117,401	163.2	91.0	12.6	16.1	25.7	39.5
Totals, Penn.	4,709	1,550,227	29.4	70.5	266,780	20.8	443,656	40.1	456,908	24,790	5.7	39,642	9.5	1,093,319	241,990	28.4	404,014	58.6	329.2	56.6	20.8	94.3	40.1
Grand totals	10,698	2,126,323	37.0	63.0	317,685	19.5	603,139	39.6	787,338	17,526	2.3	52,891	7.2	1,338,985	330,150	32.7	550,258	69.8	198.8	32.6	19.5	56.5	39.6
United States Census, Decade Ending 1890																							
New Castle Del.	435	97,182	26.8	73.2	19,466	25.0	42,385	77.3	26,038	—2,928	—1.0	—1,295	—4.7	71,144	22,394	45.9	43,680	159.0	223.4	44.8	25.0	97.4	77.3
Cecil . . Md.	377	25,851	67.7	32.3	—1,257*	—4.6	1,989	8.3	17,493	—2,058	—1.1	—6,369	—26.7	8,358	801	1.1	8,358		68.6	—3.3	—4.6	5.3	8.3
Atlantic, N.J.	569	28,836	33.9	66.1	10,132	54.2	17,050	144.6	9,782	—437	—4.3	—528	—5.1	19,054	10,569	124.6	17,578	1,190.9	50.6	17.8	54.2	29.9	144.6
Burlington "	871	58,528	73.8	26.2	3,126	5.6	8,798	17.7	43,166	1,256	2.9	—170	—0.4	15,362	1,870	13.9	8,968	140.3	67.2	3.6	5.6	10.1	17.7
Camden . . "	222	87,687	21.1	78.9	24,745	39.3	53,230	154.5	18,544	4,527	32.3	—1,555	—7.7	69,143	20,218	41.3	54,785	381.6	394.9	111.4	39.3	262.4	198.0
Cumberland "	500	45,438	44.4	55.6	7,751	20.6	22,833	101.0	20,490	1,404	7.5	5,112	33.9	25,248	6,347	33.6	17,721	235.4	90.9	15.5	20.6	45.7	101.0
Gloucester "	332	28,649	78.7	21.3	2,763	10.6	10,205	55.3	22,548	559	2.5	5,638	33.3	6,101	2,204	56.6	4,567	297.7	86.2	8.2	10.6	23.5	37.5
Hunterdon "	437	35,355	79.8	20.2	—3,215	—8.3	1,701	5.1	28,213	—3,384	—10.7	—4,568	—5.3	7,142	169	2.4	3,260	84.4	80.9	—7.3	—8.3	3.9	5.1
Mercer . . . "	226	79,978	20.8	79.2	21,917	37.7	42,559	113.7	16,635	—792	—4.5	—2,586	—13.4	63,343	22,709	55.9	45,145	248.1	353.8	96.9	37.7	188.3	113.7
Middlesex "	312	61,754	40.2	59.8	9,468	18.1	26,942	77.4	24,796	—2,937	—10.6	3,542	16.7	36,958	12,405	50.5	23,400	172.6	197.9	30.4	18.1	86.4	77.4
Monmouth "	479	69,128	67.6	32.4	13,590	24.5	29,782	75.7	46,746	1,594	3.5	7,400	18.8	22,382	11,996	115.5	22,382	...	144.3	28.4	24.5	62.2	75.7
Ocean . . . "	584	15,974	98.3	1.7	1,519	10.5	4,798	43.0	15,703	1,282	8.9	4,527	40.5	271	237	697.0	271	. .	27.5	2.7	10.5	8.3	43.0
Salem . . . . "	343	25,451	68.7	31.3	572	2.3	2,693	12.0	17,277	—1,411	—7.6	—141	—0.8	7,874	1,983	33.7	2,834	56.2	73.3	1.7	2.3	7.8	12.0
Somerset "	305	28,311	67.7	32.3	1,149	4.2	6,254	28.3	19,156	—818	—4.1	—2,901	—13.2	9,155	1,967	27.4	9,155	.	92.8	3.8	4.2	20.5	28.3
Berks . . Penn.	865	137,327	49.6	50.4	14,730	12.0	43,509	46.4	68,078	—2,410	—3.4	747	1.1	69,249	17,140	32.8	42,762	161.4	158.7	17.0	12.0	50.3	46.4
Bucks . . . "	608	70,615	75.5	24.5	1,959	2.8	7,037	11.0	53,294	—1,405	—2.6	—2,433	—4.4	17,321	3,361	24.1	9,470	120.2	116.0	3.1	2.8	11.4	11.0
Chester . "	777	89,377	66.1	33.9	5,896	7.1	14,799	19.8	59,122	—1,247	—2.1	—3,686	—5.9	30,255	7,143	30.9	18,485	157.1	115.0	7.6	7.4	19.0	19.8
Delaware "	185	74,683	50.0	50.0	18,582	33.1	44,086	144.1	37,309	6,176	2.0	14,529	63.7	37,374	12,406	49.7	29,566	378.7	403.6	100.4	33.1	238.3	144.1
Lancaster "	941	149,095	64.0	36.0	9,648	6.9	32,781	28.2	95,370	—483	—0.5	9,429	10.6	53,725	10,131	23.2	23,652	78.6	158.4	10.2	6.9	34.8	28.2
Lehigh . . . "	344	76,631	51.4	48.6	10,662	16.2	32,878	75.1	39,363	—1,130	—2.7	5,567	16.5	37,268	11,792	46.3	27,311	274.3	222.7	31.0	16.2	95.6	75.1
Montgomery "	484	123,290	56.9	43.1	26,796	27.8	52,790	74.9	70,149	3,791	5.7	13,629	24.1	53,141	23,005	76.3	39,161	280.1	254.7	55.4	27.8	109.1	74.9
Northampton "	372	84,220	43.1	56.9	13,908	19.8	36,316	75.8	36,299	—1,216	—3.2	4,245	13.2	47,921	15,124	46.1	32,071	202.3	226.3	37.3	19.8	97.5	75.8
Philadelphia "	133	1,046,964	.....	100.0	199,794	23.6	481,435	85.1	. . .	. . . .	.....	....	......	1,046,964	199,794	23.6	481,435	85.1	7,871.9	1,502.2	23.6	3,619.8	85.1
Totals, Del.	435	97,182	26.8	73.2	19,466	25.0	42,385	77.3	26,038	—2,928	—1.0	—1,295	—4.7	71,144	22,394	45.9	43,680	159.0	223.4	44.8	25.0	97.4	77.3
Totals, Md.	377	25,851	67.7	32.3	—1,257	—4.6	1,989	8.3	17,493	—2,058	—1.1	—6,369	—26.7	8,358	801	1.1	8,358	. .	68.6	—3.3	—4.6	5.3	8.3
Totals, N. J.	5,177	564,789	50.1	49.9	93,517	19.8	226,845	67.1	282,756	843	3.0	16,770	6.3	282,033	92,674	48.9	210,075	291.9	109.1	18.1	19.8	43.8	67.1
Totals, Penn.	4,709	1,852,202	24.8	75.2	301,975	19.5	745,631	67.4	458,984	2,076	0.5	41,718	10.0	1,393,218	299,899	27.4	703,913	102.1	393.3	64.1	19.5	158.4	67.4
Grand totals	10,698	2,540,424	30.9	69.1	413,701	19.4	1,016,850	66.8	785,271	—2,067	0.5	50,824	6.9	1,754,753	415,768	31.1	966,026	122.5	237.4	38.6	19.4	95.1	66.8

* Minus sign (—) denotes decrease.

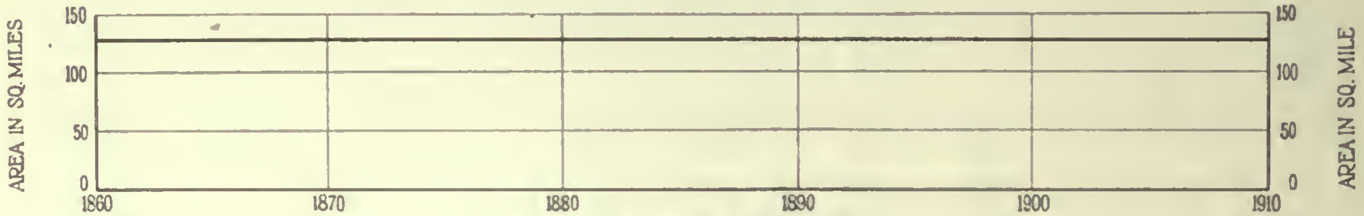
TABLE CDLXXIII, (Concluded). STATISTICS OF POPULATION OF COUNTIES IN THE STATES OF DELAWARE, MARYLAND, NEW JERSEY AND PENNSYLVANIA WITHIN 50 MILES OF PHILADELPHIA, AS SHOWN BY THE UNITED STATES CENSUS, DECADES ENDING 1860 TO 1910, INCLUSIVE

County	Area Sq. Miles	Population of County							Rural Population of County					Population of Cities and Villages					Population per Square Mile				
		Total	Per Cent in Rural Communities	Per Cent in Urban Communities	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease				Total	Increase or Decrease			
					Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860			Over Preceding Census		Over Census 1860	
					No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent		No.	Per Cent	No.	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
United States Census, Decade Ending 1900																							
New Castle . . Del.	435	109,697	21.5	78.5	12,515	12.9	54.900	100.1	23,637	—2,401	—9.2	—3.696	—13.5	86,060	14.916	20.9	58,596	213.4	252.1	28.7	12.9	126.1	100.1
Cecil . . . . . Md.	377	24,662	67.2	32.8	—1,189*	—4.6	800	3.4	16,561	—932	—5.3	—7.301	—30.6	8.101	—257	—3.1	8,101	. . . . . .	65.4	—3.2	—4.6	2.1	3.4
Atlantic. N. J.	569	46.402	20.5	79.5	17,566	61.0	34,616	293.7	9.512	—270	—2.8	—798	—7.7	36,890	17,836	93.6	35,414	2,399.3	81.5	30.9	61.0	60.8	293.7
Burlington "	815	58,241	72.5	27.5	—287	—0.5	8.511	17.1	42,227	—939	—2.2	—1,109	—2.6	16.014	652	4.2	9,620	150.4	71.5	4.3	6.4	14.4	25.2
Camden . . "	222	107,643	17.2	82.8	19,956	22.8	73,186	212.4	18.568	24	0.1	—1,531	—7.6	89.075	19.932	28.8	74,717	520.4	484.8	89.9	22.8	352.3	265.9
Cumberland . "	500	51.193	43.6	56.4	5,755	12.7	28,588	126.5	22.327	2,137	10.1	7,249	48.1	28.866	3.618	14.3	21.339	283.5	102.4	11.5	12.7	57.2	126.5
Gloucester "	332	31.905	79.5	20.5	3.256	11.4	13.461	73.0	25.369	2.821	12.5	8.459	50.0	6.536	435	7.1	5,002	326.1	96.1	9.9	11.4	33.4	53.3
Hunterdon "	437	34.507	66.4	33.6	—848	—2.4	853	2.5	22.924	—5,289	—18.4	—6,857	—23.0	11,583	4.441	62.3	7,710	199.0	78.9	—2.0	—2.4	1.9	2.5
Mercer . . . "	226	95,365	15.4	84.6	15,387	19.2	57,946	154.9	14,697	—1,938	—11.7	—4,524	—23.5	80.668	17.325	27.4	62,470	343.3	421.9	68.1	19.2	256.4	154.9
Middlesex. "	312	79,762	34.9	65.1	18.008	29.2	44,950	129.1	27,820	3,024	12.2	6.566	30.9	51,942	14.984	40.1	38,384	273.1	255.6	57.7	29.2	144.1	129.1
Monmouth "	479	82,057	55.2	44.8	12,929	18.7	42,711	108.6	45,332	—1,424	— 3.0	5,976	15.2	36,735	14.353	64.1	36,735	. . . . . .	171.3	27.0	18.7	89.2	108.6
Ocean . . . . "	637	19,747	91.4	8.6	3,773	23.6	8,571	76.7	18,057	2,354	14.9	6,881	61.6	1.690	1.419	523.6	1,690	. . . . . .	31.0	3.5	12.7	11.8	61.5
Salem . . . . "	343	25,530	60.3	39.7	379	1.5	3.072	13.7	15,382	—1,895	—10.9	—2.036	—11.7	10.148	2.274	28.9	5,108	101.3	74.4	1.1	1.5	8.9	13.7
Somerset . "	305	32.948	46.6	53.4	4,637	16.4	10.891	49.4	15,346	—3,810	—19.9	—6,711	—30.4	17,602	8.447	92.3	17,602	. . . . . .	108.0	15.2	16.4	35.7	49.4
Berks . . Penn.	865	159.615	43.5	56.5	22.288	16.2	65.797	70.1	69,372	1,294	1.9	2,041	3.0	90,243	20.994	30.3	63,756	240.7	184.5	25.8	16.2	76.1	70.1
Bucks . . "	608	71,190	66.2	33.8	575	0.8	7,612	12.0	47,119	—6,175	—11.6	—8.608	—15.4	24,071	6,750	38.9	16,220	206.6	117.1	1.1	0.8	12.6	12.0
Chester "	777	95,695	60.1	39.9	6,318	7.1	21,117	28.3	57,480	—1,642	—2.8	—5.328	—8.5	38,215	7.960	26.3	26,445	224.7	123.2	8.2	7.1	27.2	28.3
Delaware "	185	94,762	36.6	63.4	20,079	26.9	64,165	209.7	34,718	—2,591	—6.9	11,929	52.3	60.044	22.670	60.6	52,236	669.0	512.2	108.6	26.9	346.9	209.7
Lancaster "	941	159,241	55.5	44.5	10.146	6.8	42,927	36.9	88,361	—7,009	—7.3	2.120	2.5	70,880	17.155	31.9	40,807	135.7	169.2	10.8	6.8	45.6	36.9
Lehigh . "	344	93,893	44.5	55.5	17.262	22.5	50,140	114.6	41,765	2.402	6.1	7.969	23.6	52,128	14.860	39.8	42,171	423.5	272.9	50.2	22.5	145.8	114.6
Montgomery "	484	138,995	53.3	46.7	15,705	12.7	68,495	97.2	74,140	3.991	5.7	17,620	31.2	64,855	11,714	22.0	50,875	363.9	287.2	32.5	12.7	141.6	97.2
Northampton "	372	99,687	38.3	61.7	15,467	18.4	51,783	108.1	38,182	1,883	5.2	6,128	19.1	61,505	13,584	28.3	45,655	288.0	267.9	41.6	18.4	139.1	108.1
Philadelphia "	133	1,293.697	. . . . .	100.0	246.733	23.6	728,168	128.8	. . . .	. . . .	. . . . . .	. . . .	. . . . . .	1,293,697	246.733	23.6	728.168	128.8	9.727.0	1.855.1	23.6	5.474.9	128.8
Totals, Del.	435	109,697	21.5	78.5	12,515	12.9	54,900	100.1	23,637	—2,401	—9.2	—3,696	—13.5	86.060	14.916	20.9	58,596	213.4	252.1	28.7	12.9	126.1	100.1
Totals, Md.	377	24,662	67.2	32.8	—1,189	—4.6	800	3.4	16,561	—932	—5.3	—7.301	—30.6	8,101	—257	—3.1	8,101	. . . . . .	65.4	—3.2	—4.6	2.1	3.4
Totals, N. J.	5,177	665,300	41.7	58.3	100.511	17.8	327,356	96.8	277,551	—5.205	—1.8	11,565	4.3	387,749	105,716	37.5	315,791	438.8	128.5	19.4	17.8	63.2	96.8
Totals, Penn.	4,709	2,206,775	20.4	79.6	354,573	19.1	1,100,204	99.4	451,137	—7.847	—1.7	33,871	8.1	1,755,638	362,420	26.0	1,066,333	154.7	468.6	75.3	19.1	233.7	99.4
Grand totals	10.698	3,006,434	25.6	74.4	466,410	18.4	1,483,260	97.4	768,886	—16.385	—2.1	34,439	4.7	2,237,548	482,795	27.5	1,448,821	183.7	281.0	43.6	18.4	138.7	97.4
Uuited States Census, Decade Ending 1910																							
New Castle . . Del.	435	123,188	20.5	79.5	13,491	12.3	68,391	224.8	25,244	1.607	6.8	—2,089	—7.6	97,944	11,884	13.8	70,480	257.7	283.2	31.1	12.3	157.2	124.8
Cecil . . . . Md.	377	23.759	67.5	32.5	—903	—3.7	—103	—0.4	16,045	—516	—3.1	—7,817	—32.8	7,714	—387	—4.8	7,714	. . . . . .	63.0	—2.4	—3.7	—0.3	—0.4
Atlantic N. J.	569	71,894	13.6	86.4	25,492	54.9	60,108	510.0	9,790	278	2.9	—520	—5.0	62,104	25,214	68.3	60,628	4.107.6	126.3	44.7	54.9	105.6	510.0
Burlington "	815	66,565	73.3	26.7	8,324	14.3	16,835	33.9	48,774	6,547	15.5	5,438	12.5	17,791	1,777	11.1	11,397	178.2	81.7	10.2	14.3	24.6	43.1
Camden . . "	222	142,029	16.1	83.9	34,386	31.9	107.572	312.2	22,902	4.334	23.3	2,803	13.9	119,127	30,052	33.7	104,769	729.7	639.7	154.9	31.9	507.2	382.8
Cumberland "	500	55,153	42.1	57.9	3,960	7.7	32.548	144.0	23,211	884	3.9	8,133	53.9	31.942	3,076	10.6	24,415	324.4	110.3	7.9	7.7	63.1	144.0
Gloucester "	332	37.368	65.0	35.0	5,463	17.1	18.924	102.6	24.282	—1.087	—4.3	7,372	43.6	13.086	6,550	100.2	11,552	753.1	112.5	16.4	17.1	49.8	79.4
Hunterdon "	437	33.569	61.8	38.2	—938	—2.7	—85	—0.3	20,735	—2,189	—9.5	—9,046	—30.4	12,834	1,251	10.8	8,961	231.2	76.8	—2.1	—2.7	—0.2	—0.3
Mercer . . "	226	125.657	15.9	84.1	30,292	31.8	88.238	235.8	20.032	5,335	36.3	811	4.2	105,625	24,957	30.9	87,427	480.4	556.0	134.1	31.8	390.5	235.8
Middlesex "	312	114,426	26.9	73.1	34.664	43.5	70.614	228.8	30,764	2.944	10.5	9.510	44.7	83,662	31.720	61.1	70,104	507.1	366.7	111.1	43.5	255.2	228.8
Monmouth "	470	94.734	41.9	58.1	12,677	15.4	55,388	140.8	39,705	—5,617	—12.4	359	0.9	55,029	18,294	49.7	55,029	. . . . . .	197.7	26.4	15.4	115.6	140.8
Ocean . . . . "	637	21.318	83.9	16.1	1,571	8.0	10,142	90.7	17,895	—102	—0.9	6.719	60.1	3,423	1,733	102.5	3,423	. . . . . .	33.5	2.5	8.0	14.3	74.5
Salem . . . . "	343	26.909	57.4	42.6	1,469	5.7	4,541	20.2	15.487	105	0.7	—1,931	—11.1	11,512	1.364	13.4	6,472	128.4	78.7	4.3	5.7	13.2	20.2
Somerset "	305	38.820	46.3	53.7	5,872	17.8	16,763	76.0	17,962	2,616	17.0	—4.095	—18.6	20,858	3.256	18.5	20.858	. . . . . .	127.3	19.3	17.8	55.0	76.0
Berks . Penn.	865	183.222	35.7	64.3	23,607	14.8	89.404	95.3	65,401	—3.971	—5.7	—1,930	—2.9	117,821	27.578	30.6	91,334	344.8	211.8	27.3	14.8	103.4	95.3
Bucks . . "	608	76,530	59.2	40.8	5,340	7.5	12.952	20.4	45,333	—1.786	—3.8	—10,394	—18.9	31,197	7,126	33.7	23,346	297.4	125.8	8.7	7.5	21.3	20.4
Chester "	777	109,213	53.2	46.8	13,518	14.1	34.635	46.4	58,135	655	1.1	—4,673	—7.4	51,078	12,863	33.6	39,308	334.0	140.5	17.3	14.1	44.5	46.4
Delaware "	185	117,906	35.1	64.9	23.144	24.4	87,309	285.4	41,375	6,657	19.2	18,586	81.6	76,531	16,487	27.5	68,723	880.2	637.3	125.1	24.4	472.0	285.4
Lancaster "	941	167,029	51.4	48.6	7,788	4.9	50,715	43.6	85,804	—2.557	—2.9	—437	—0.5	81,225	10,345	14.6	51,152	170.6	177.5	8.3	4.9	53.9	43.6
Lehigh. "	344	118,832	35.3	64.7	21,939	26.6	75,079	171.6	41,915	150	0.4	8,119	24.0	76,917	24,780	47.6	66,960	672.5	345.4	72.5	26.6	218.3	171.6
Montgomery "	484	169,590	51.3	48.7	30,595	22.0	99,090	140.6	86,935	12.795	17.3	30,415	53.8	82,655	17,800	27.4	68,675	491.2	350.4	63.2	22.0	204.8	140.6
Northampton "	372	127,667	28.3	71.7	27,980	28.1	79,763	166.5	36,104	—2.078	—5.4	4.050	12.6	91,563	30,058	48.9	75,713	477.7	343.2	75.3	28.1	214.4	166.5
Philadelphia "	133	1.549,008	. . . . .	100.0	255.311	19.7	983,479	173.9	. . . .	. . . .	. . . . . .	. . . .	. . . . . .	1,549,008	255,311	19.7	983.479	173.9	11.646.6	1,919.6	19.7	7,394.5	173.9
Totals, Del.	435	123,188	20.5	79.5	13,491	12.3	68.391	124.8	25,244	1,607	6.8	—2,089	—7.6	97,944	11,884	13.8	70,480	257.7	283.2	31.1	12.3	157.2	124.8
Totals, Md.	377	23,759	67.5	32.5	—903	—3.7	—103	—0.4	16.045	—516	—3.1	—7,817	—32.8	7,714	—387	—4.8	7,714	. . . . . .	63.0	—2.4	—3.7	—0.3	—0.4
Totals, N. J.	5,177	828.532	35.2	64.8	163,232	24.5	490,588	145.1	291,530	13,988	5.0	25,553	9.6	536,993	149,244	38.5	465,035	646.3	160.0	31.5	34.5	94.7	145.1
Totals, Penn.	4,709	2,618,997	17.6	82.4	412,222	18.7	1,512,426	136.7	461,002	9,865	2.2	43,736	10.5	2,157,995	402,357	22.9	1,468,690	213.1	556.2	87.6	18.7	321.3	136.7
Grand totals	10,698	3,594,476	22.1	77.9	588,042	19.6	2,071,302	136.0	793,830	24,944	3.2	59,383	8.1	2.800,646	563,098	25.2	2,011,919	255.1	336.0	55.0	19.6	193.7	136.0

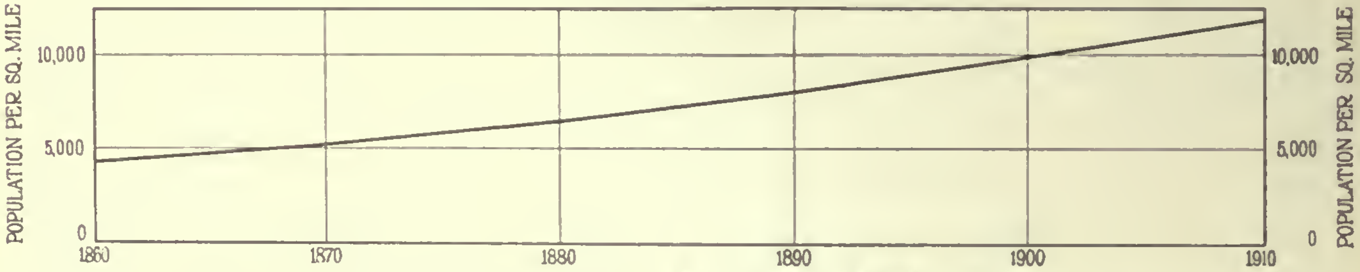
* Minus sign (—) denotes decrease.



Population of Philadelphia 1860-1910



Area of Philadelphia 1860-1910



Population per Square Mile of Philadelphia 1860—1910

FIG. 706. CHANGES IN POPULATION AND AREA OF THE CITY OF PHILADELPHIA, FROM UNITED STATES CENSUS AND MUNICIPAL REPORTS, 1860-1910

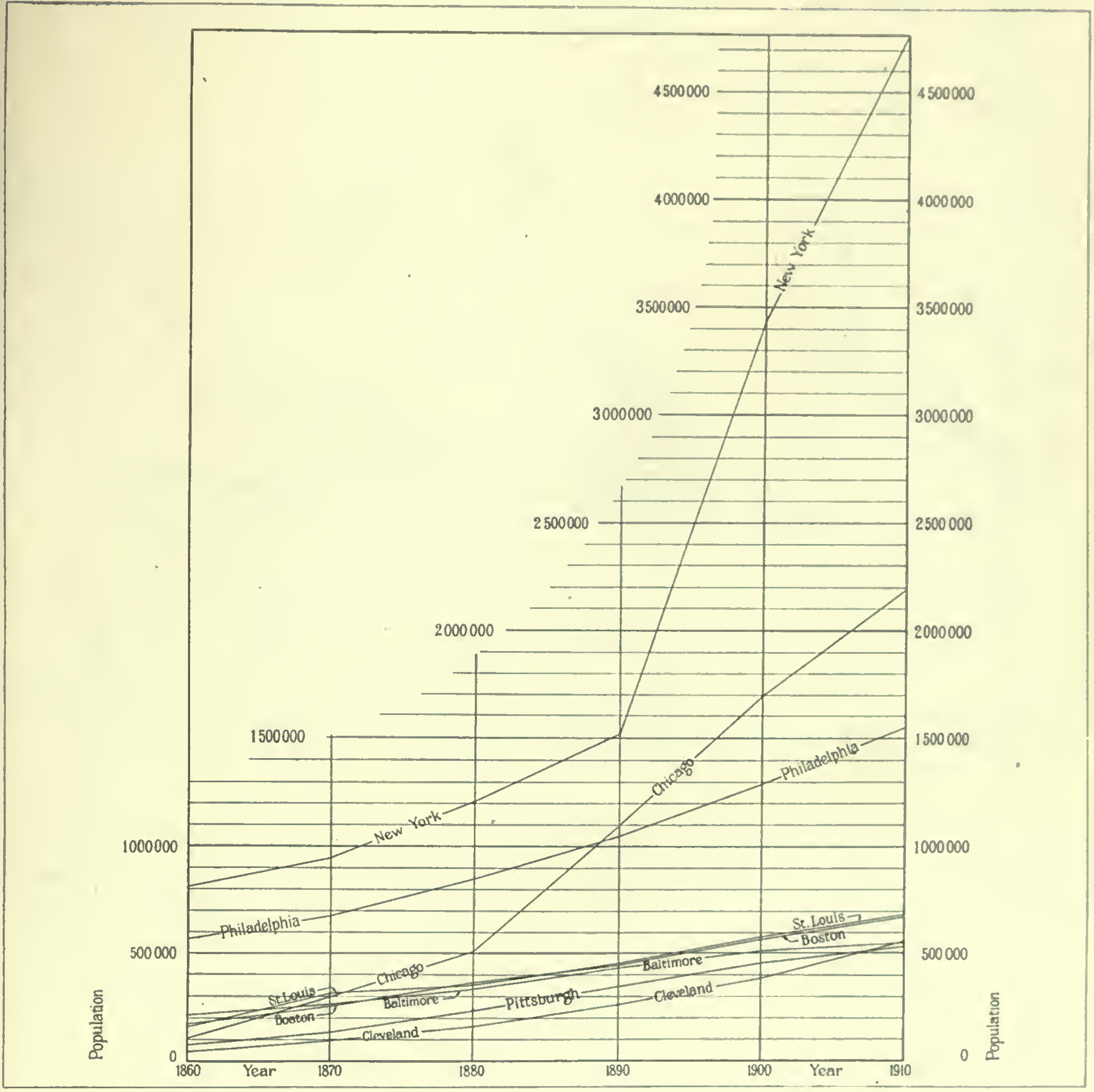
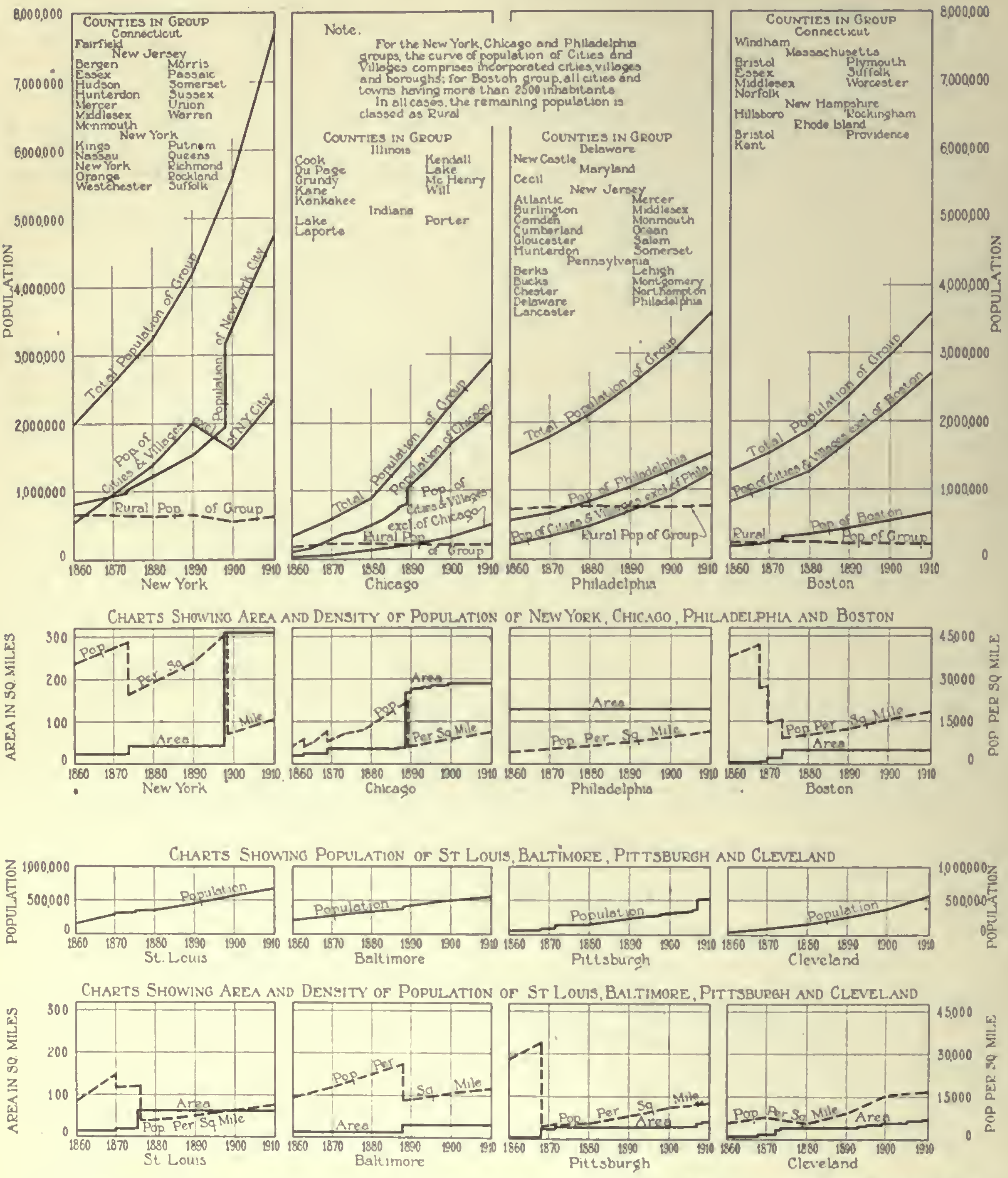


FIG. 707. CHANGES IN POPULATION OF THE EIGHT LARGEST CITIES OF THE UNITED STATES AS SHOWN BY THE UNITED STATES CENSUS, 1860-1910



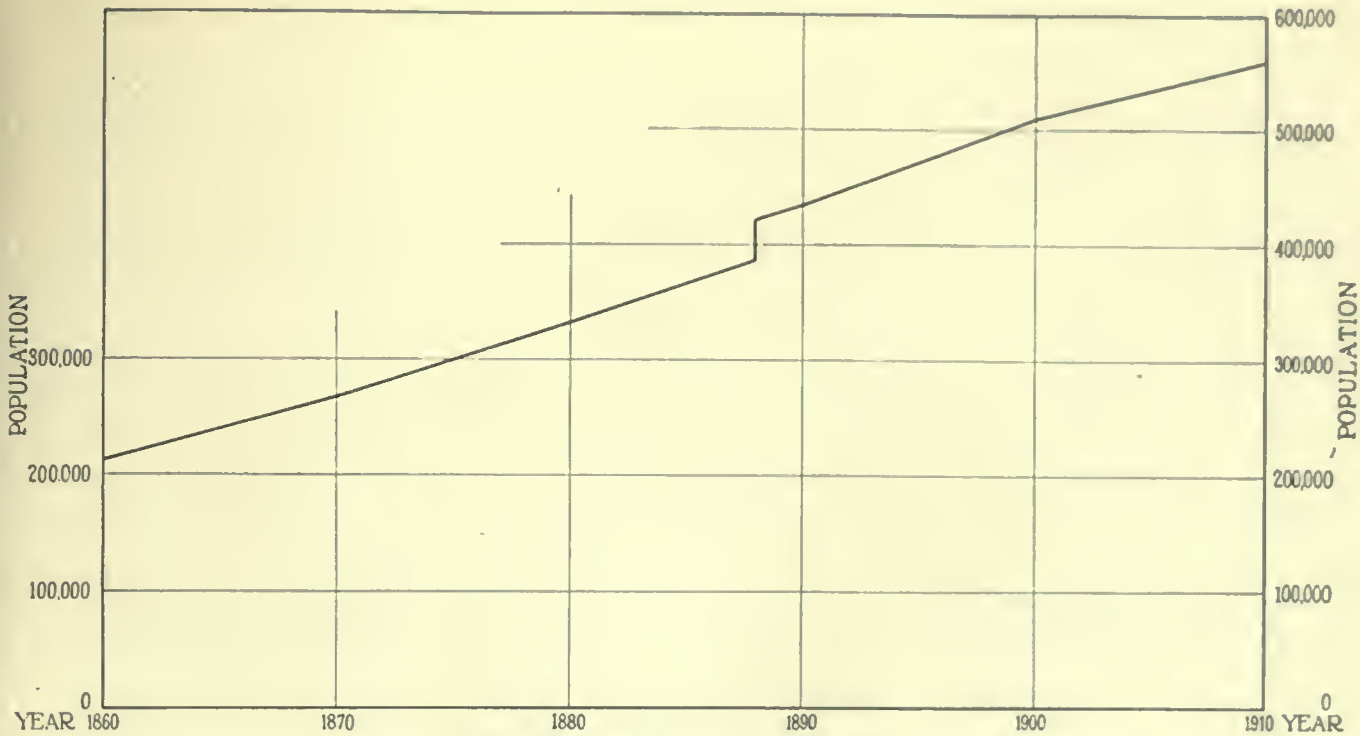
Note.
For the New York, Chicago and Philadelphia groups, the curve of population of Cities and Villages comprises incorporated cities, villages and boroughs; for Boston group, all cities and towns having more than 2500 inhabitants.
In all cases, the remaining population is classed as Rural

CHARTS SHOWING AREA AND DENSITY OF POPULATION OF NEW YORK, CHICAGO, PHILADELPHIA AND BOSTON

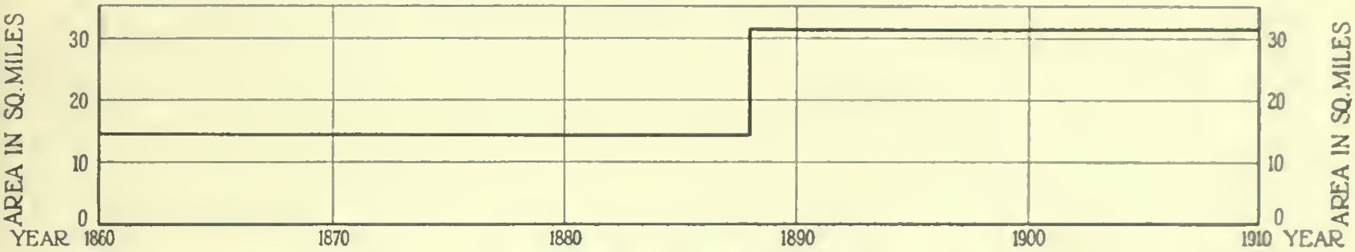
CHARTS SHOWING POPULATION OF ST LOUIS, BALTIMORE, PITTSBURGH AND CLEVELAND

CHARTS SHOWING AREA AND DENSITY OF POPULATION OF ST LOUIS, BALTIMORE, PITTSBURGH AND CLEVELAND

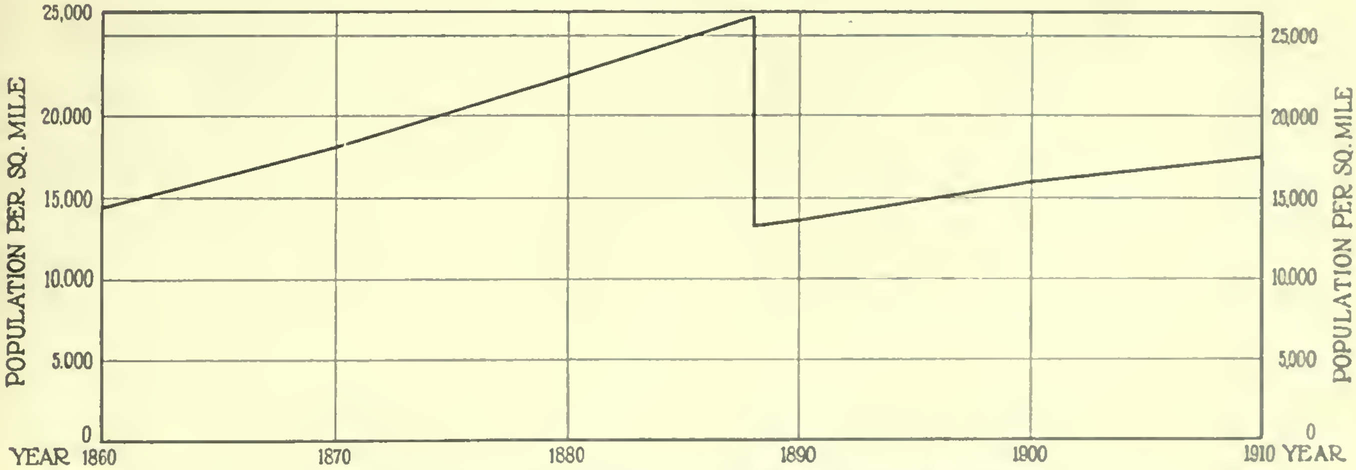
FIG. 708. CHANGES IN URBAN AND RURAL POPULATION OF COUNTIES WITHIN 50 MILES OF NEW YORK, CHICAGO, PHILADELPHIA AND BOSTON, 1860-1910



POPULATION OF BALTIMORE 1860–1910

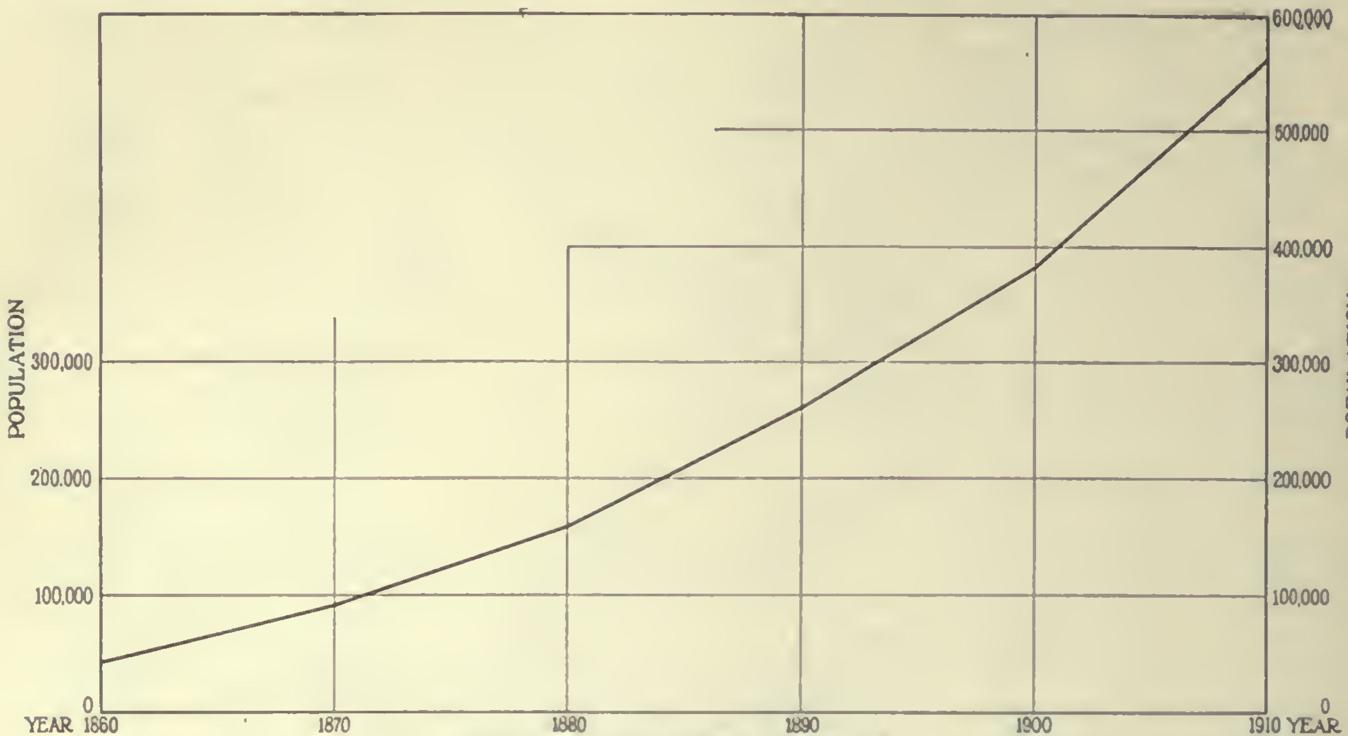


AREA OF BALTIMORE 1860-1910

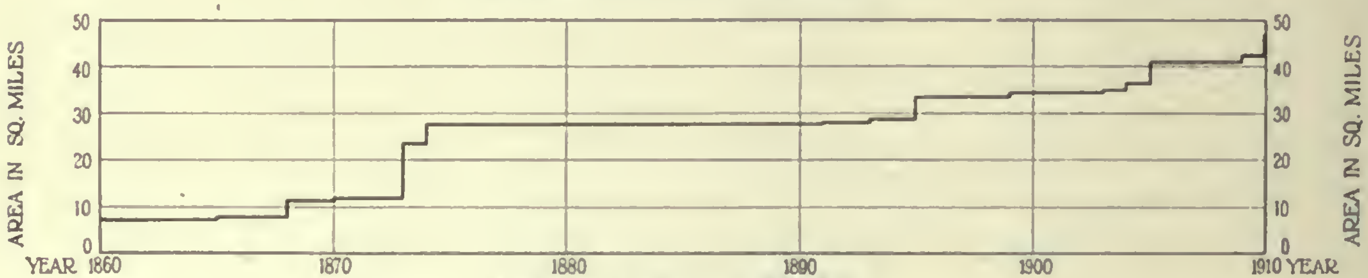


POPULATION PER SQUARE MILE OF BALTIMORE 1860-1910

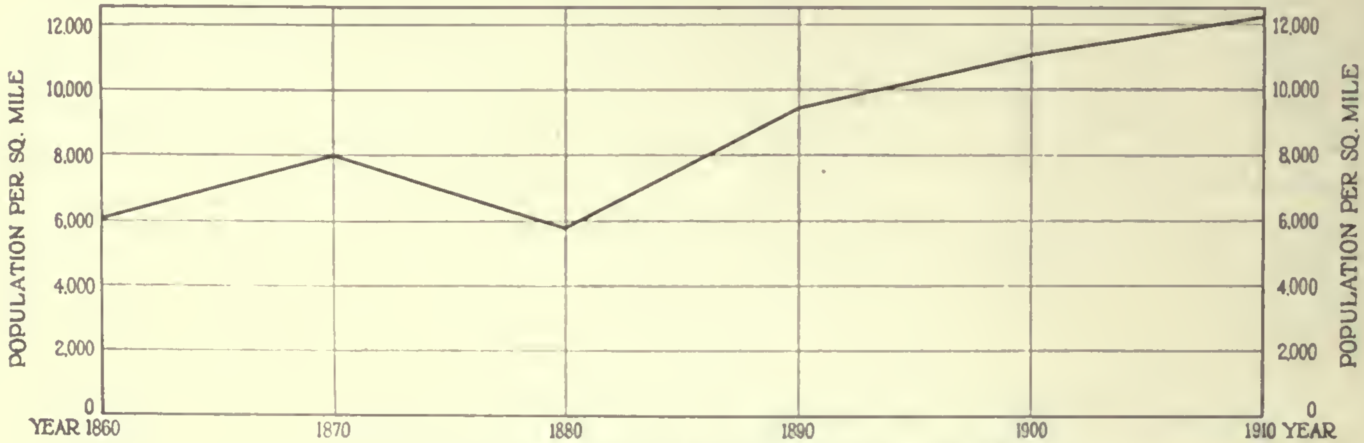
FIG. 709. CHANGES IN POPULATION AND AREA OF THE CITY OF BALTIMORE, AS SHOWN BY THE UNITED STATES CENSUS AND BY MUNICIPAL REPORTS, 1860-1910



POPULATION OF CLEVELAND 1860-1910

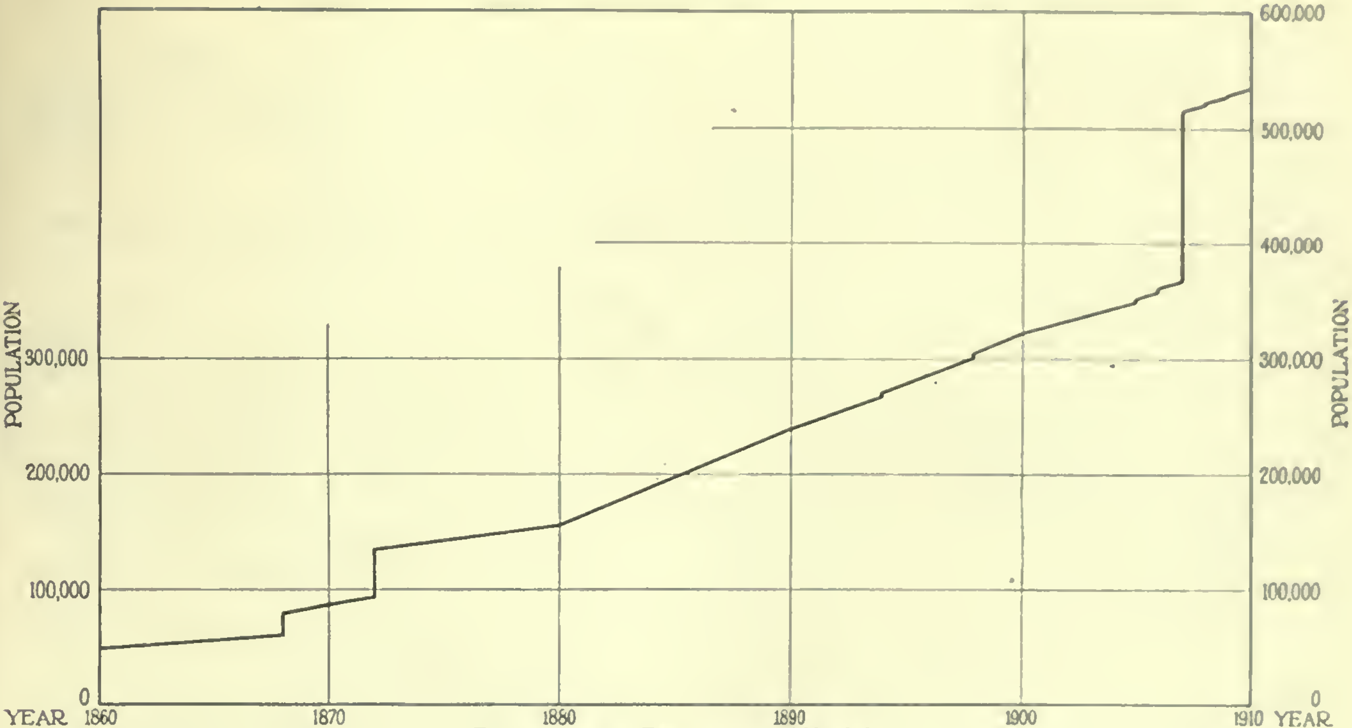


AREA OF CLEVELAND 1860-1910

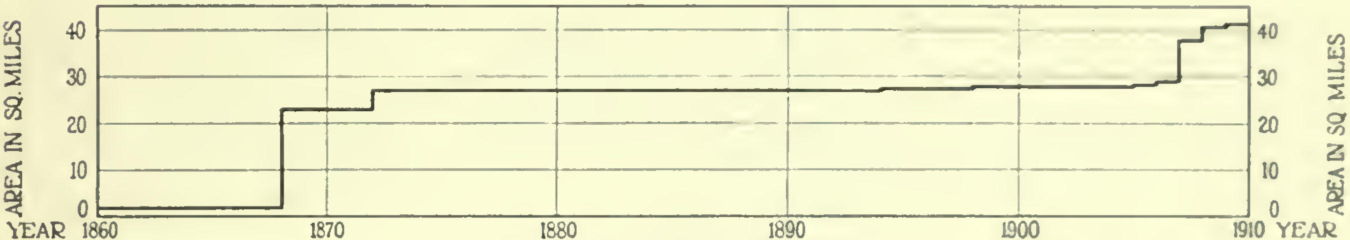


POPULATION PER SQUARE MILE OF CLEVELAND 1860-1910

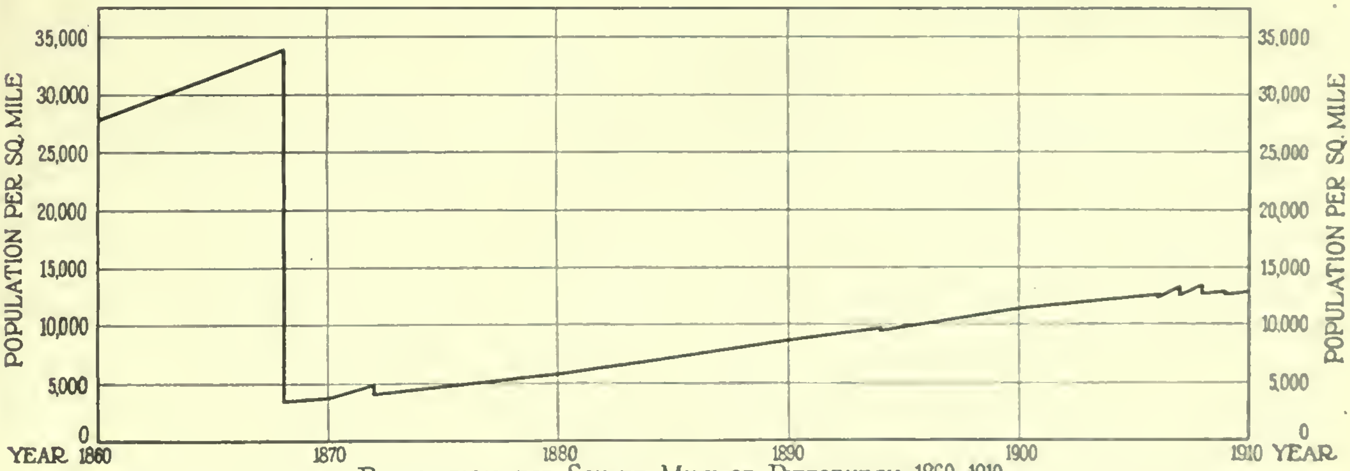
FIG. 710. CHANGES IN POPULATION AND AREA OF THE CITY OF CLEVELAND, AS SHOWN BY THE UNITED STATES CENSUS AND BY MUNICIPAL REPORTS, 1860-1910



Population of Pittsburgh 1860-1910

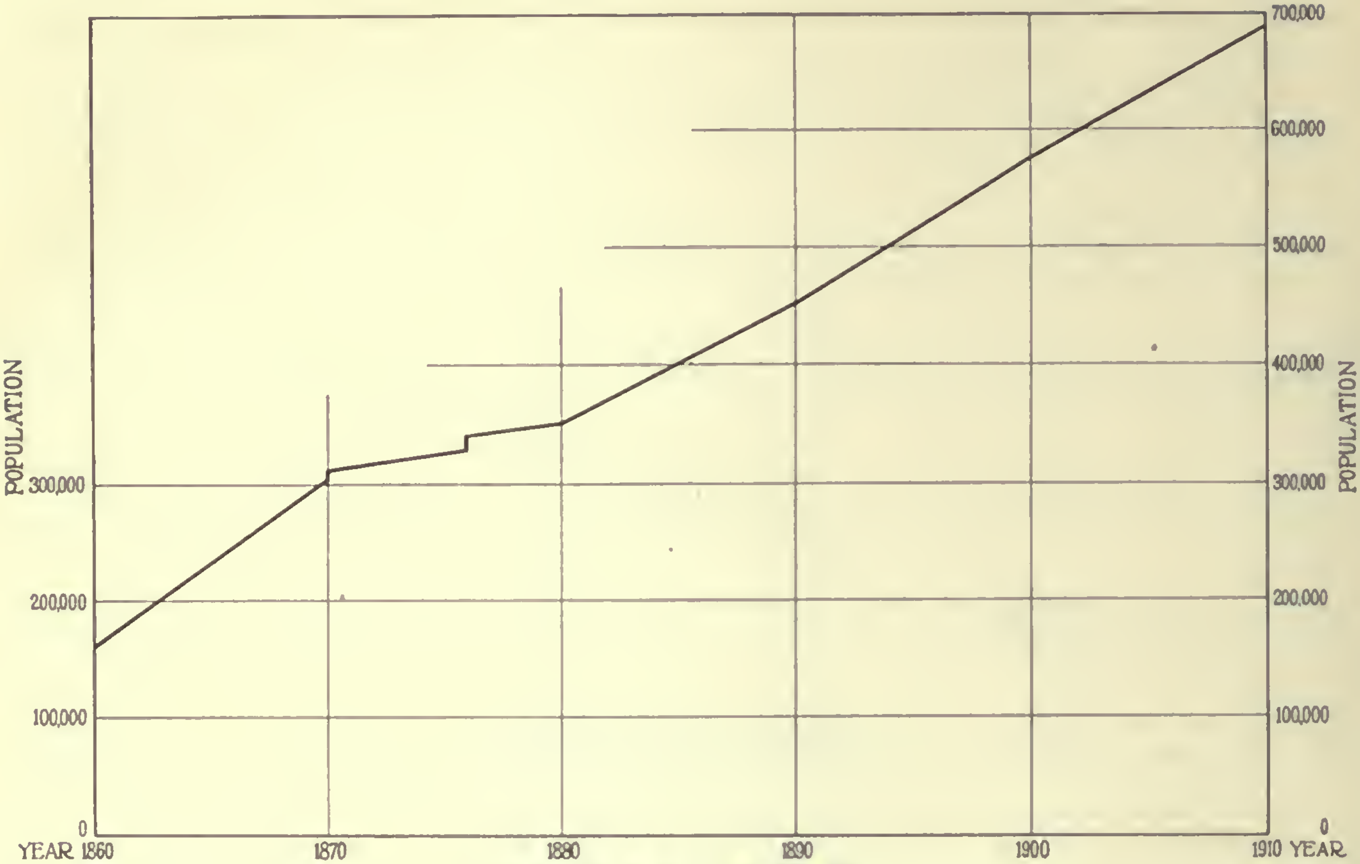


Area of Pittsburgh 1860-1910

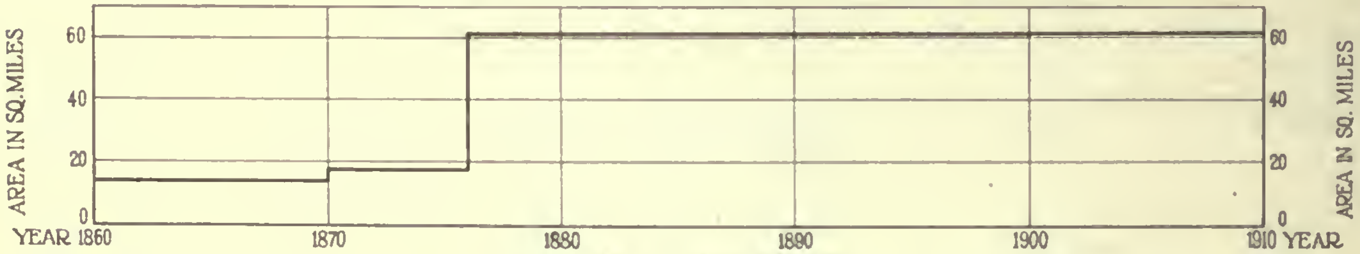


Population per Square Mile of Pittsburgh 1860-1910

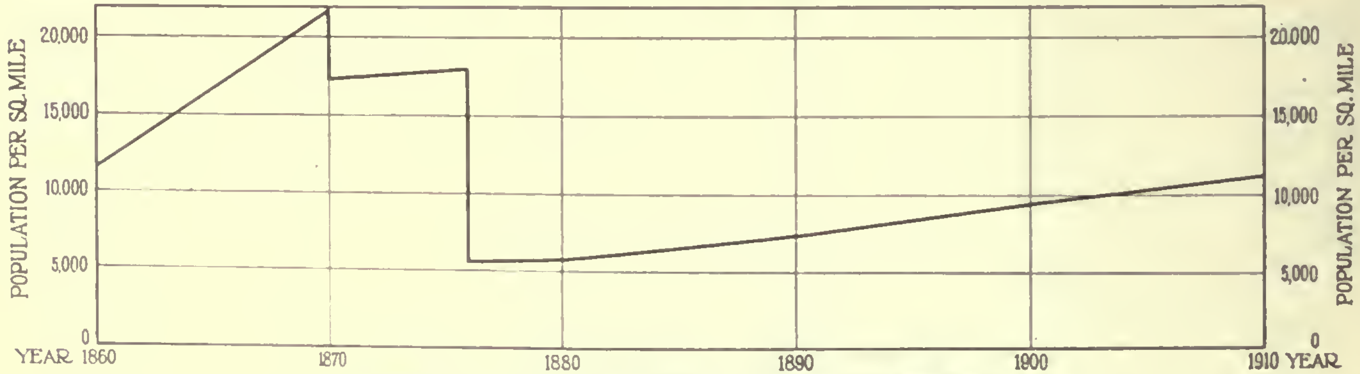
FIG. 711. CHANGES IN POPULATION AND AREA OF THE CITY OF PITTSBURGH, AS SHOWN BY THE UNITED STATES CENSUS AND BY MUNICIPAL REPORTS, 1860-1910



Population of St. Louis 1860-1910



Area of St. Louis 1860-1910



Population per Square Mile of St. Louis 1860-1910

FIG. 712. CHANGES IN POPULATION AND AREA OF THE CITY OF ST. LOUIS, AS SHOWN BY THE UNITED STATES CENSUS AND BY MUNICIPAL REPORTS, 1860-1910

IMPORTANCE OF CHICAGO AS A RAILROAD CENTER

701.34 Growth of Chicago's Railroad Mileage: The growth of the railroad lines entering Chicago is indicated by table CDLXXIV, which presents statistics for 1860 and 1869, for comparison with the years 1903 and 1912.

TABLE CDLXXIV. GROWTH OF CHICAGO TRUNK LINES

Item	1860	1869	1903	1912
1	2	3	4	5
Number of lines	11	12	21	23
Mileage	4,700	7,000	67,000	78,000
Gross earnings	$13,000,000	$50,000,000	$655,697,254	$956,588,049

The growth in number and importance of the trunk lines is characteristic of Chicago's entire growth in transportation activities. Of the total of 39 railroad companies by which Chicago is now served, 25 maintain passenger and freight service and 23 are classed as trunk lines.

The mileage of main, industrial and yard tracks in the Chicago District is shown by table CDLXXV.

TABLE CDLXXV. MILEAGE OF RAILROAD TRACKS WITHIN THE COMMITTEE'S AREA OF INVESTIGATION, 1912

Class	Miles
Main track	1,746
Industrial tracks owned by railroad companies	390
Industrial tracks owned by industries	222
Yard tracks	2,144
Total mileage	4,502

Table CDLXXVI presents a comparison of Chicago with three other railroad centers as to number and aggregate annual gross earnings of railroads of the first class, that is, those earning annually more than $1,000,000.

TABLE CDLXXVI. COMPARISON OF FOUR RAILROAD CENTERS. RAILROADS OF THE FIRST CLASS

City	Number of Railroads of the First Class	Aggregate Annual Gross Earnings
Chicago	**25**	**$850,000,000**
New York	14	560,000,000
Philadelphia	9	430,000,000
Boston	3	115,000,000

METEOROLOGICAL CONDITIONS OF CHICAGO

701.35 Chicago's Meteorological Conditions Compared with those of Other American Cities: Meteorological conditions of Chicago's location, which have been subject to extended observation, are, on the whole, favorable to the maintenance of a clear and wholesome atmosphere. They are superior to those of many other cities of the United States and of Europe. The climate, although changeable and occasionally extreme in temperature, is distinctly healthful and energizing. The death rate (14.7 per 1,000 in 1910) is lower than that of any other great city in the United States.

Chicago's percentage of possible sunshine is higher than the average for American cities and much higher than that of other cities similarly situated with respect to the Great Lakes.

A comparison of the meteorological conditions of Chicago with those of 38 other American cities, relative to maximum and average wind velocities, mean maximum and mean minimum temperatures, relative humidity, precipitation and percentage of possible sunshine, is given in tables CDLXXVII and CDLXXVIII for the seven-year period from 1906 to 1912, inclusive.*

INFLUENCES AFFECTING THE LOCATION OF RAILROAD LINES AND TERMINALS IN CHICAGO

701.36 Location of the Illinois Central Railroad on the Lake Front: The Illinois Central Railroad located its lines along the Lake Front in response to the requirements of an ordinance passed by the Chicago City Council. This ordinance was contrary to the preferences expressed by the officials of the railroad company, who desired to locate the railroad along the south branch of the Chicago River. The ordinance shows that not only did the city prefer to have the railroad locate where it is, but that it expected and actually received an incidental advantage.

Section 7 of the ordinance provided that the railroad company should, within three years after its acceptance of the ordinance, construct and thereafter maintain a continuous wall or structure of stone masonry, pier work or other sufficient material, from the north side of Randolph Street to the southern boundary of the city, at such distances outside of the tracks of the road as might be expedient, "which structure and work shall be of sufficient strength and magnitude to protect the entire front of said city between the north side of Randolph Street and its southern boundary from further damage or injury from the waters of Lake Michigan."

In its advocacy of this ordinance, the "Daily Democrat" of April 2, 1852, urged that the ordinance containing the provisions referred to be speedily passed, in order that the lake front might be at once protected through the work of the railroad company. The ordinance carried by a vote of 10 to 6, two aldermen being absent. The six aldermen who voted against it were referred to as the "river aldermen," because of the fact that they desired the railroad to be located, in accordance with the wishes of President Schuyler, on the west side of the south branch of the river. These aldermen and the influences behind them were strong enough to secure the insertion of a section which

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* See Archives of the Committee, Vol. J 3.

TABLE CDLXXVII. COMPARISON OF CHICAGO WITH 38 OTHER AMERICAN CITIES AS TO AVERAGE WIND VELOCITY AND MEAN TEMPERATURE, 1906-1912

WIND VELOCITY, Miles Per Hour				TEMPERATURE, Degrees F.			
MAXIMUM		AVERAGE		MEAN MAXIMUM		MEAN MINIMUM	
New York	90	Cleveland	14.6	New Orleans	77.3	St. Paul	35.5
Buffalo	84	Buffalo	14.6	Birmingham	72.6	Denver	37.3
Kansas City	74	Toledo	14.1	Los Angeles	71.9	Spokane	38.7
Memphis	72	**Chicago**	**14.0**	Atlanta	70.0	Syracuse	38.9
Detroit	70	New York	13.3	Memphis	70.0	Grand Rapids	39.4
Columbus	70	Detroit	13.2	Nashville	69.3	Albany	39.4
Toledo	70	Syracuse	11.7	Richmond	67.6	Milwaukee	39.7
Pittsburgh	69	Kansas City	11.3	Louisville	66.4	Rochester	39.8
Chicago	**68**	Columbus	11.2	St. Louis	64.4	Scranton	40.3
Cleveland	68	Atlanta	11.1	Washington	64.4	Buffalo	40.3
New Orleans	66	Milwaukee	10.7	Cincinnati	64.3	Detroit	40.5
Atlanta	66	Boston	10.6	Kansas City	64.0	Providence	40.9
Syracuse	66	St. Paul	10.5	Baltimore	63.7	Toledo	41.7
Omaha	66	St. Louis	10.5	Denver	63.1	New Haven	42.1
Grand Rapids	66	Pittsburgh	10.5	Philadelphia	62.5	Omaha	42.2
San Francisco	64	Philadelphia	10.1	San Francisco	61.8	Cleveland	42.2
Seattle	64	Indianapolis	9.9	Indianapolis	61.2	Boston	42.6
Providence	62	Grand Rapids	9.7	Columbus	61.2	Columbus	43.2
St. Paul	62	New Haven	9.2	Portland	60.9	Pittsburgh	43.6
Nashville	62	Providence	9.1	Pittsburgh	60.8	**Chicago**	**43.7**
Richmond	61	Omaha	8.9	Omaha	60.2	Indianapolis	44.0
St. Louis	60	Rochester	8.8	New York	59.6	Seattle	44.4
Louisville	60	Memphis	8.5	New Haven	58.7	Portland	45.3
Milwaukee	58	New Orleans	8.3	Scranton	58.4	New York	45.7
Indianapolis	58	Seattle	8.2	Boston	58.1	Washington	45.8
Rochester	58	San Francisco	8.2	Toledo	58.1	Cincinnati	46.3
Birmingham	58	Louisville	8.1	Spokane	58.0	Kansas City	47.1
Denver	55	Richmond	8.1	Seattle	57.5	Philadelphia	47.2
New Haven	54	Denver	7.8	Albany	57.2	Baltimore	47.6
Philadelphia	54	Albany	7.8	**Chicago**	**57.1**	St. Louis	47.6
Boston	52	Nashville	7.6	Providence	57.0	Louisville	47.9
Scranton	52	Baltimore	7.1	Cleveland	56.4	Richmond	47.9
Washington	51	Birmingham	7.1	Grand Rapids	56.4	Nashville	49.9
Spokane	48	Scranton	7.1	Detroit	56.2	San Francisco	50.2
Albany	48	Cincinnati	6.9	Rochester	55.9	Atlanta	52.8
Baltimore	46	Washington	6.6	Syracuse	54.9	Los Angeles	53.0
Cincinnati	45	Portland	6.3	Buffalo	54.0	Memphis	53.9
Los Angeles	42	Spokane	6.1	Milwaukee	53.9	Birmingham	54.1
Portland	40	Los Angeles	5.8	St. Paul	53.4	New Orleans	62.3

TABLE CDLXXVIII. COMPARISON OF CHICAGO WITH 38 OTHER AMERICAN CITIES AS TO RELATIVE HUMIDITY, PRECIPITATION AND PERCENTAGE OF POSSIBLE SUNSHINE, 1906–1912

RELATIVE HUMIDITY—Per Cent		PRECIPITATION—Inches		SUNSHINE—Per Cent of Possible	
Seattle	78.7	New Orleans	61.2	Los Angeles	71.0
New Orleans	78.1	Birmingham	53.7	Denver	66.3
Buffalo	77.7	Atlanta	47.0	Kansas City	63.9
San Francisco	77.4	Memphis	45.2	Memphis	63.1
Richmond	76.9	New Haven	45.1	New York	61.3
Syracuse	76.4	Philadelphia	44.9	St. Paul	60.6
Grand Rapids	75.9	Nashville	44.7	Baltimore	60.2
Milwaukee	75.7	Louisville	44.7	Richmond	59.7
Detroit	75.2	Richmond	42.6	Omaha	59.3
Chicago	**74.1**	Baltimore	42.1	Boston	58.7
Portland	73.7	Washington	41.9	Atlanta	58.1
Toledo	73.1	New York	40.7	New Orleans	58.1
Birmingham	73.1	Portland	40.0	New Haven	58.1
Albany	72.9	St. Louis	39.5	St. Louis	57.9
Cleveland	72.9	Cincinnati	38.3	**Chicago**	**57.4**
Rochester	72.3	Indianapolis	37.9	Cincinnati	57.3
Scranton	72.3	Providence	37.3	Nashville	57.3
Providence	72.0	Scranton	36.5	Birmingham	57.3
Nashville	71.9	Buffalo	36.1	Louisville	57.1
Indianapolis	71.7	Kansas City	35.9	Philadelphia	56.7
Columbus	71.7	Columbus	35.5	Milwaukee	56.6
Atlanta	71.6	Boston	35.4	Columbus	55.4
Memphis	71.1	Toledo	34.5	Washington	54.6
Washington	71.1	Pittsburgh	34.3	Indianapolis	54.6
New York	70.4	Grand Rapids	33.9	Providence	54.6
Boston	70.4	Cleveland	33.6	Rochester	52.7
Pittsburgh	70.2	**Chicago**	**33.5**	Spokane	52.7
St. Paul	70.1	Syracuse	31.3	Toledo	52.6
New Haven	70.1	Detroit	31.0	Cleveland	50.6
St. Louis	69.8	Seattle	31.0	Buffalo	49.5
Philadelphia	69.6	Albany	30.7	Detroit	49.3
Louisville	68.9	Rochester	30.3	Pittsburgh	49.0
Baltimore	68.7	Milwaukee	29.6	Grand Rapids	48.1
Los Angeles	68.1	St. Paul	27.4	Albany	47.4
Cincinnati	68.0	Omaha	24.9	Portland	44.4
Kansas City	68.0	San Francisco	21.5	Seattle	42.9
Omaha	68.0	Spokane	15.6	Scranton	38.4
Spokane	63.3	Los Angeles	15.3	San Francisco	..
Denver	53.6	Denver	15.3	Syracuse	[illegible]

required the railroad company to construct the track now known as the St. Charles Air Line, connecting the trackage along the shore of the lake with that in the river district of the city. Section 4 of the ordinance reads as follows:

> "Permission and right-of-way are hereby given to the said company to construct and maintain a side track from its main track, beginning at or south of 12th Street, proceeding through said street or such line as may be prescribed by the Common Council, westerly to the south branch of the Chicago River; thence crossing the said south branch by a bridge, or other mode to be approved by the Common Council, which shall not obstruct navigation; thence, proceeding northerly to Kinzie Street, following as far as practicable the streets nearest to said branch, on such sides of the center of streets as the Common Council may prescribe; said track not to be laid west of the west line of Canal Street; and also a track leading from the last mentioned track at or near its intersection with the eastern line of the said southern branch of the Chicago River, along the line of said south branch, into Market Street, following, as far as possible, the streets nearest the river and on such sides of such streets as the Common Council may direct; thence along the west line of Market Street northerly to Lake Street."

The construction of the breakwater by the terms of the ordinance was commenced in September, 1852, and completed in 1854; thereafter, the city had no trouble from the encroachment of the lake. Prior to 1860, the company had spent approximately $500,000 on lake front protection work. During the construction period of 1856, "the total amount expended for lake front protection, as shown by the records of the railroad company, amounted to $368,166.92, which amount was charged to capital; the total amount expended and charged to capital from 1856 to 1913, inclusive, was $1,800,000; there have been charges to maintenance from 1908 to 1913, ranging from $8,000 to $28,000 per annum."

These figures show that the expense incurred by the company in complying with the requirements of the ordinance under which it was permitted to enter the city, has been continuous up to the present time.

SPREAD OF SOLID MATERIALS IN THE SMOKE OF LOCOMOTIVES

701.37 Solids in Locomotive Smoke and Atmospheric Pollution: The extent to which the solid particles contained in locomotive smoke affect the atmosphere as a polluting agency is dependent, in a large measure, upon the length of time they may remain in the air, and upon the distance they may be transported from the point of emission by air currents before settling to the ground. The larger particles settle quickly. The finer cinders and dust particles settle more slowly, their rate of descent depending upon their size, form and specific gravity, and upon the condition of the atmosphere and the influence of the air currents. Very small particles may remain in the atmosphere a long time and be distributed over large areas. The effect of large cinders as polluting constituents of the atmosphere is obviously local. For the purpose of ascertaining the facts concerning the physical properties of particles emitted and the distance traversed by them, an extensive series of tests was undertaken and conducted by the Committee.

The tests were conducted throughout the two zones of investigation, both in switching yards and on the main lines of railroads. In switching yards 24 tests were made, 18 in Zone A and 6 in Zone B. On main lines 76 tests were made, 46 in Zone A and 30 in Zone B. Of the total number of tests, 64 were conducted in Zone A and 36 in Zone B. The points at which tests were conducted are shown by the accompanying map, fig. 713.

701.38 Description of Tests: The methods employed involved the use of a series of metallic pans to receive the falling particles. These were set in line on the lee side of the railroad track, at right angles to, and at prescribed distances from, the center line of the track. Ten galvanized iron pans, each 18 inches square and 6 inches deep, constituting an open receptacle with an area of 2.25 square feet, and each bearing a number, were used. Each pan was fitted with a horizontal wire screen of four meshes to the inch, placed one inch above the bottom to prevent the disturbance of deposited particles by passing currents of air. It was found that such a screen constituted a satisfactory baffle. The distances of the several pans from the center line of track and the distances between consecutive pans of the series were normally as follows:

PAN NO.	NO. FT. FROM CENTER TRACK	NO. FT. FROM	PAN NO.
1	20	..	..
2	40	20	1
3	60	20	2
4	80	20	3
5	100	20	4
6	125	25	5
7	150	25	6
8	200	50	7
9	250	50	8
10	350	100	9

This arrangement was adhered to except in a few instances in which limitations of space made it impossible to set out all of the pans, or in which contingencies arose that made it necessary to eliminate a pan from a test.

A diagram showing the arrangement of pans for a typical test is presented as fig. 714.

Three, and sometimes four, experienced men were employed in the conduct of each test. The pans were carefully set at the prescribed locations, and the line of pans was patrolled during the period of the test to prevent interference with the ordinary precipitation,

FIG. 713. LOCATION OF POINTS AT WHICH TESTS WERE CONDUCTED TO DETERMINE THE SPREAD OF SOLIDS IN LOCOMOTIVE SMOKE
(Arrows Indicate Direction of Wind During Test)

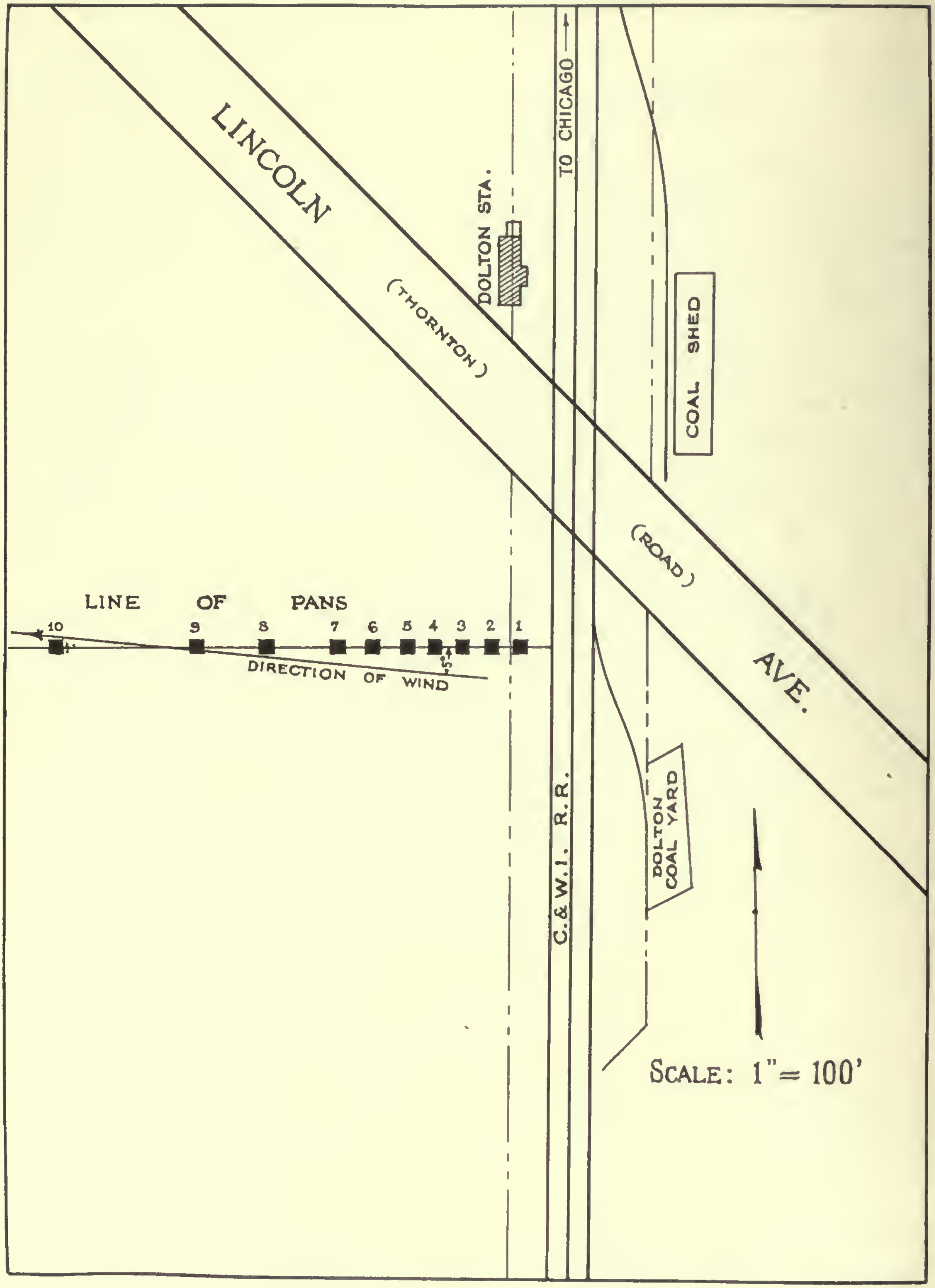

FIG. 714. ARRANGEMENT OF PANS FOR A TYPICAL TEST

or molestation of the materials deposited. As the presence of moisture from rain or snow made difficult the collection of fine particles from the pans, all tests in which the pans contained either moisture or snow were rejected. All tests were conducted during the day. Observations recorded for each test included a definition of the location of each pan, the direction and velocity of the wind and other weather conditions, the time at which locomotives or trains passed, the speed of passing, and much other information which at the time of the test gave promise of being of value. The average duration of each test was 5.5 hours.

At the close of a test, the contents of the pans were carefully collected and placed in clean, dry, numbered bottles, the numbering of the bottles corresponding to the numbering of the pans in which the collection was made. The bottles were sealed and labeled with the name of the railroad on the line of which the test was made, and with the location and number of the test.

In the laboratory the contents of each bottle were separated into five parts as follows:

1. Coarse cinders.
2. Fine cinders.
3. Fuel dust.
4. Other inorganic matter.
5. Organic matter.

The coarse cinders, fine cinders and fuel dust were separated by the use of screens of 20 and 200 meshes per inch. With the aid of a magnifying glass* an expert separated the inorganic and organic matter from the matter emitted from locomotives.

It was intended that each test should be of the same duration and should be conducted during the same hours of the day, but unfavorable weather conditions and other contingencies made necessary the acceptance of some tests of shorter duration. In order to place all tests on the same basis as to time, the results of each were reduced to a basis of one hour, necessitating the assumption that the rate of deposit during a test was constant.

701.39 Average Density of Traffic: The average density of railroad traffic for one day of 24 hours during the tests is shown by table CDLXXIX.

TABLE CDLXXIX. AVERAGE NUMBER OF LOCOMOTIVES AND CARS PASSING TEST LOCATIONS DAILY

Place	Zone	No. Locomotives	No. Cars	No. Test Locations
1	2	3	4	5
Yard	A	241	2194	18
	B	79	1031	6
Main Line	A	190	1908	46
	B	71	1194	30

These differences account for the variation in the total quantity of materials collected in different tests and groups of tests.

701.40 Velocity of the Wind: The velocity and direction of the wind are indicated for each test in fig. 713. The average wind velocity per hour recorded for the tests is shown by table CDLXXX.

TABLE CDLXXX AVERAGE WIND VELOCITY RECORDED DURING TESTS

Place	Zone	Miles per Hour	No. Tests
1	2	3	4
Yard	A	14.7	18
	B	19.4	6
Main line	A	14.3	46
	B	14.4	30

701.41 Influence of Air Currents: From ocular observation of the movement of dust particles in the air in the immediate vicinity of railroad tracks, it was apparent that the velocity of the wind in the vicinity of the pans was affected by passing traffic, but the extent of the disturbance was indeterminate. The velocity of the wind, whether due to natural causes or to passing traffic, is a factor in agitating matter suspended in the atmosphere or lying loose upon the ground. No attempt was made to separate matter deposited as a result of wind action from that emitted from locomotives during the hours of the tests, nor to separate matter thrown into the atmosphere by the natural force of the wind from that projected into it by the action of railroad traffic. No relationship was established between the amount of solids emitted by locomotives and the amount precipitated on, and in the vicinity of, railroad tracks.

701.42 Results: The results constitute an excellent record of the character and distribution of the solid constituents of locomotive smoke. Because of varying conditions due to local influences, they do not constitute a satisfactory basis upon which to determine the quantity of solids deposited.

The materials collected were not all of fuel origin. The strong air currents, stimulated by moving trains, resulted in the collection of solids from the road-bed and the surrounding territory, as well as those from locomotive stacks. Of the materials collected, it was assumed that all of the cinders and fuel dust came from locomotives and that the non-fuel materials came from other sources. This assumption was not entirely correct, since some of the cinders and fuel dust collected may have had their origin in other smoke producing plants operating in the vicinity of the test ground, but the errors arising from this source were considered negligible. It was also assumed that all of the cinders and fuel dust collected in the pans were emitted on the day of the test, though it is probable that some of the matter collected was emitted prior to the day of the test and was taken up by the wind and deposited in the pans on the day of the test.

The character of solids deposited in the pans in switching yards and on main lines, by zones, is shown by table CDLXXXI.

The results as to the spread of solids are shown diagrammatically by figs. 715 to 719, inclusive, in which the average amount of each kind of solids deposited in each pan is expressed in per cent of the total solids deposited in the pan in question.

The five different classes of constituents treated in the tabulation and in the diagrams are expressed in terms of the ratio that the weight of each constituent collected in a given pan bears to the total weight of all constituents collected in that pan. In no case is

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* A record of the results of the laboratory analyses is preserved in the Archives of the Committee, Vols. G 50 and G 51.

TABLE CDLXXXI. AVERAGE AMOUNT OF EACH CLASS OF SOLIDS DEPOSITED IN PANS

(In per cent of total)

Pan No.	Place	Zone	From Locomotives			Not from Locomotives		Total
			Coarse Cinders	Fine Cinders	Fuel Dust	Inorganic Matter	Organic Matter	
1	2	3	4	5	6	7	8	9
1	Yard	A	58.03	34.40	2.98	4.14	0.45	100
		B	19.86	22.85	12.12	44.49	0.68	100
	Main line	A	57.55	24.68	4.51	12.38	0.88	100
		B	54.62	25.25	1.82	17.26	1.05	100
2	Yard	A	57.16	35.75	2.60	4.13	0.36	100
		B	43.66	22.25	9.99	23.77	0.33	100
	Main line	A	62.63	26.91	4.35	4.97	1.14	100
		B	56.02	28.25	1.86	11.88	1.99	100
3	Yard	A	62.84	30.88	2.16	3.84	0.28	100
		B	54.98	22.30	6.46	15.82	0.44	100
	Main line	A	58.54	28.06	5.50	6.77	1.13	100
		B	59.11	26.23	1.92	11.65	1.09	100
4	Yard	A	65.08	29.19	2.11	3.17	0.45	100
		B	56.86	29.04	2.95	10.10	1.05	100
	Main line	A	54.24	36.27	5.08	2.88	1.53	100
		B	52.02	32.28	2.93	11.30	1.47	100
5	Yard	A	62.10	27.69	3.16	6.67	0.38	100
		B	51.05	28.20	2.47	17.94	0.34	100
	Main line	A	47.54	36.56	7.26	6.12	2.52	100
		B	34.63	24.04	9.93	30.05	1.35	100
6	Yard	A	55.41	34.14	4.20	5.41	0.84	100
		B	9.81	11.65	3.91	74.00	0.63	100
	Main line	A	43.00	38.71	8.32	6.02	3.95	100
		B	33.15	31.59	17.30	15.38	2.58	100
7	Yard	A	52.77	37.49	3.66	4.90	1.18	100
		B	21.38	23.70	7.57	46.13	1.22	100
	Main line	A	42.37	36.65	8.55	10.21	2.22	100
		B	35.11	34.80	5.56	21.12	3.41	100
8	Yard	A	35.53	46.54	6.02	10.79	1.12	100
		B	12.29	24.81	14.78	45.52	2.60	100
	Main line	A	39.90	28.61	8.28	19.35	3.86	100
		B	26.74	36.76	7.84	24.33	4.33	100
9	Yard	A	21.34	37.28	13.08	26.70	1.60	100
		B	19.11	22.44	7.14	48.65	2.66	100
	Main line	A	30.97	33.98	9.84	19.45	5.76	100
		B	10.81	20.07	3.89	58.75	6.48	100
10	Yard	A	30.76	47.77	9.56	9.38	2.53	100
		B	9.82	22.73	11.15	55.14	1.16	100
	Main line	A	20.92	32.66	12.40	22.76	11.26	100
		B	14.34	27.57	6.13	47.69	4.27	100

FIG. 715. AVERAGE AMOUNT OF COARSE CINDERS DEPOSITED IN EACH PAN IN PER CENT OF THE TOTAL MATERIALS DEPOSITED IN THE PAN IN QUESTION

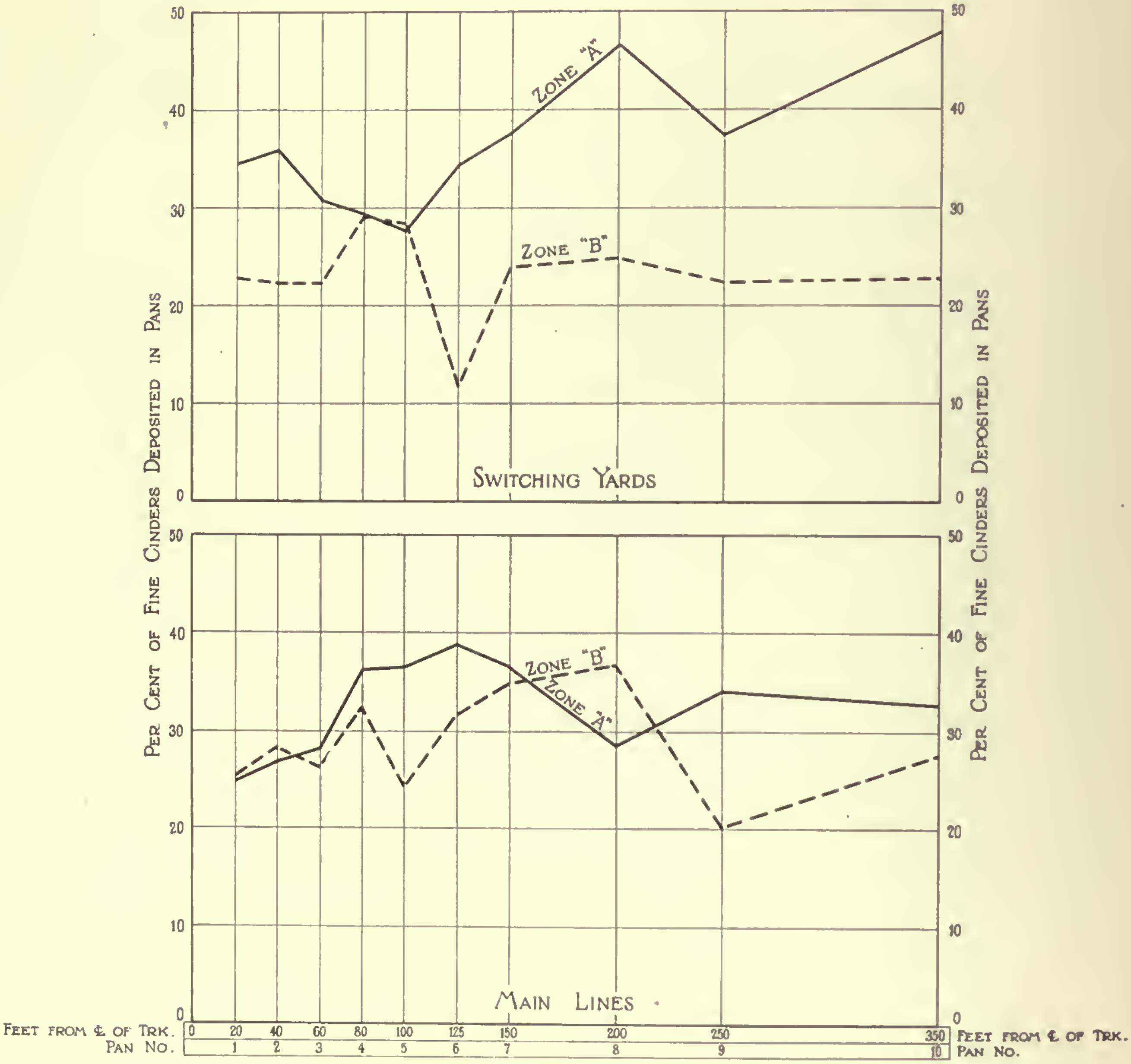

FIG. 716. AVERAGE AMOUNT OF FINE CINDERS DEPOSITED IN EACH PAN IN PER CENT OF THE TOTAL MATERIALS DEPOSITED IN THE PAN IN QUESTION

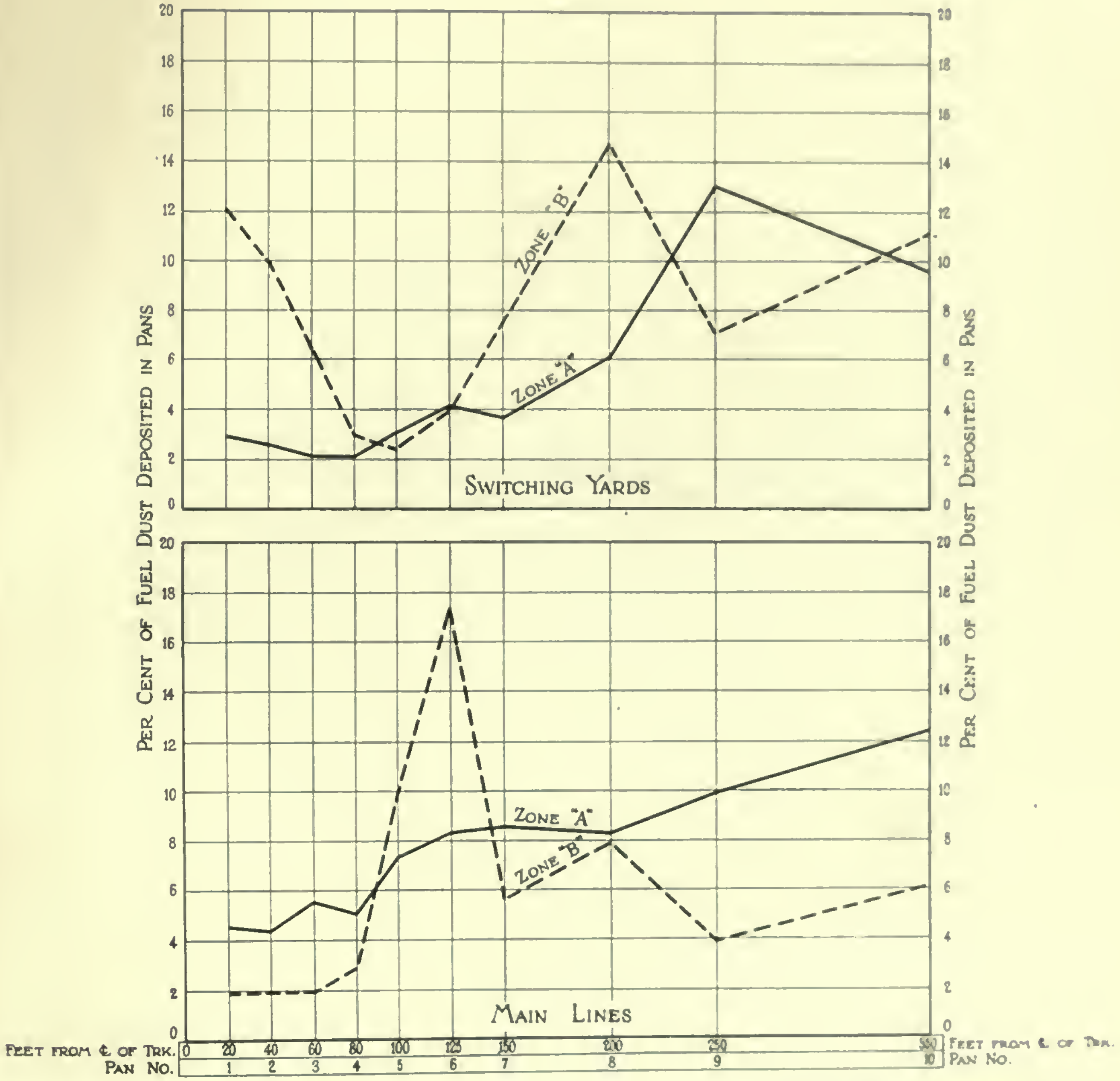

FIG. 717. AVERAGE AMOUNT OF FUEL DUST DEPOSITED IN EACH PAN IN PER CENT OF THE TOTAL MATERIALS DEPOSITED IN THE PAN IN QUESTION

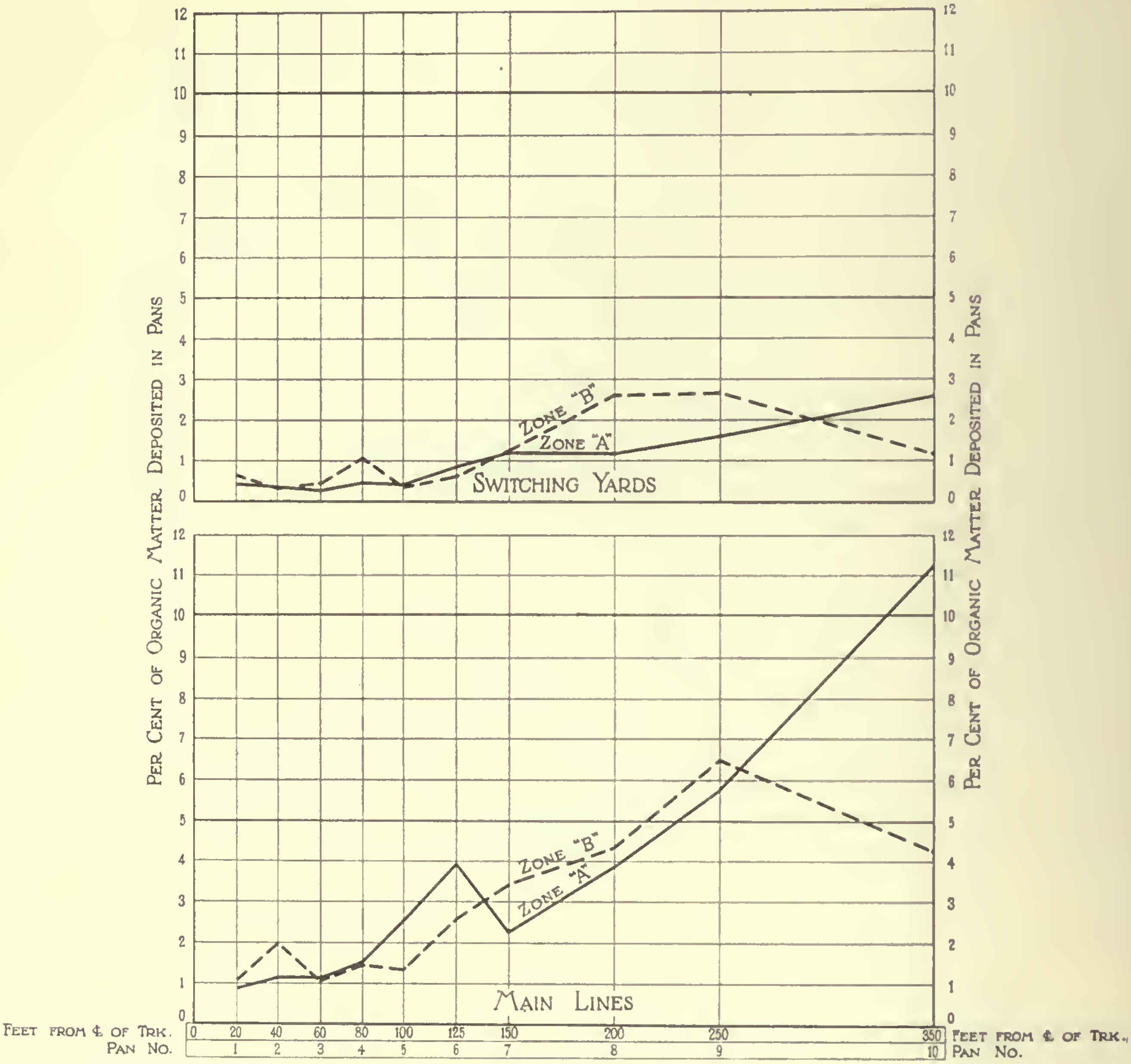

FIG. 718. AVERAGE AMOUNT OF ORGANIC MATTER DEPOSITED IN EACH PAN IN PER CENT OF THE TOTAL MATERIALS DEPOSITED IN THE PAN IN QUESTION

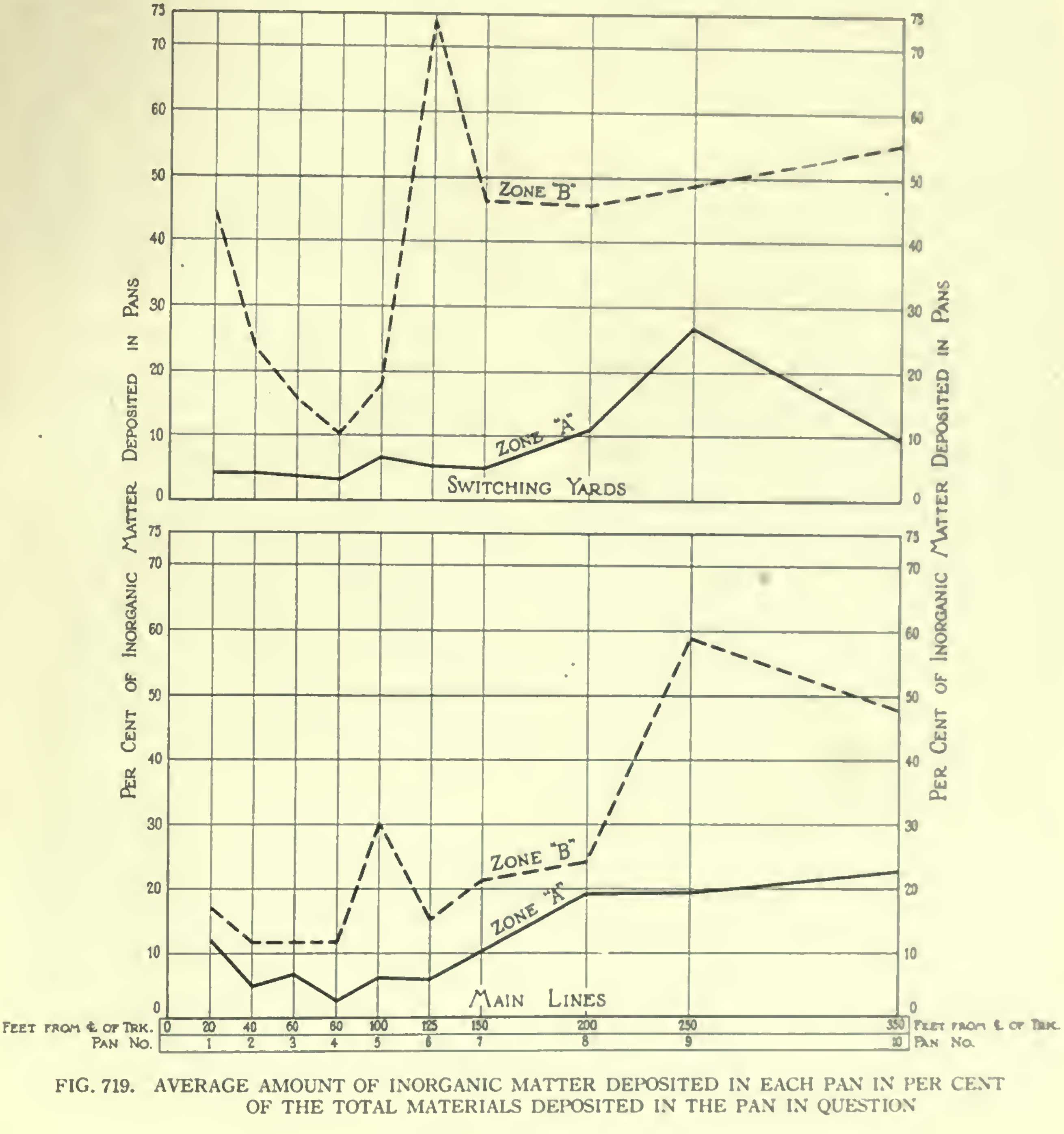

FIG. 719. AVERAGE AMOUNT OF INORGANIC MATTER DEPOSITED IN EACH PAN IN PER CENT OF THE TOTAL MATERIALS DEPOSITED IN THE PAN IN QUESTION

the percentage based on the combined weight of the solid constituents collected in pans bearing different numbers, or on the combined weight of solids collected in tests in different services or in different zones.

701.43 Distances from the Tracks of Maximum and Minimum Deposits of Each Kind of Material: The results recorded in table CDLXXXI indicate the location of the pan which received the maximum and minimum deposits of each kind of material. The significance of these facts is emphasized by the statements which follow.

Coarse Cinders

The percentage of coarse cinders, considered as matter deposited from locomotives, was found to be greater for each pan location in switching yards in Zone A than in Zone B. In switching yards in Zone A, the maximum percentage of coarse cinders was shown to be at pan No. 4, or 80 feet from the center of the track, and the minimum at pan No. 9, or 250 feet from the center of track, while in Zone B the maximum was at pan No. 4, or 80 feet from the center of track, and the minimum at pan No. 6, or 125 feet from the center of track. On main lines in Zone A, the maximum percentage of coarse cinders was shown to be at pan No. 2, or 40 feet from the center of track, and the minimum at pan No. 10, or 350 feet from the center of track. On main lines in Zone B, the maximum percentage of coarse cinders was at pan No. 3, or 60 feet from center of track, and the minimum at pan No. 9, or 250 feet from the center of track. The mean percentage in switching yards was highest at pan No. 4, or 80 feet from the center of track, and lowest at pan No. 9, or 250 feet from the center of track. On main lines, the mean percentage was highest at pan No. 2, or 40 feet from the center of track, and lowest at pan No. 10, or 350 feet from the center of track.

Fine Cinders

The percentage of fine cinders was found to be greater for each pan location in switching yards in Zone A than in Zone B, except for pan location No. 5, in which the amounts were practically the same. The mean percentage deposited in switching yards was highest at pan location No. 8, Zone A, or 200 feet from the center of track, and lowest at pan location No. 5, or 100 feet from the center of track. On main lines, the percentage of fine cinders was greater for each pan location in Zone A than in Zone B, except for pan locations Nos. 1 and 2, in which the percentages were practically the same, and for pan location No. 8, in which the percentage was considerably less in Zone A than in Zone B. The mean percentage of fine cinders was highest at pan location No. 7, or 150 feet from the center of track, and lowest at pan location No. 1, or 20 feet from the center of track.

Fuel Dust

The percentage of fuel dust in switching yards was found to be greater in some pan locations in Zone A than in Zone B, and less in others. On main lines, the percentage was greater for each pan location in Zone A than in Zone B, except for pan locations Nos. 5 and 6. The maximum percentage of fuel dust deposited in switching yards in Zone A was at pan No. 9, or 250 feet from the center of track. In Zone B, the maximum was at pan No. 8, or 200 feet from the center of track, and the minimum at pan No. 5, or 100 feet from the center of track. On main lines, the maximum percentage in Zone A was at pan location No. 10, or 350 feet from the center of track, and the minimum at pan No. 2, or 40 feet from the center of track. In Zone B the maximum was at pan No. 6, or 125 feet from the center of track, and the minimum at pan No. 1, or 20 feet from the center of track.

Inorganic Matter not from Locomotives

The percentage of inorganic matter not from locomotives was found to be less for each pan location in Zone A than in Zone B, both in switching yards and on main lines. The mean percentage in switching yards was highest at pan location No. 8, or 200 feet from the center of track, and lowest at pan location No. 4, or 80 feet from the center of track. On main lines, the mean percentage was highest at pan location No. 6, or 125 feet from the center of track, and lowest at pan No. 2, or 40 feet from center of track. The large percentages of this material in Zone B, both in switching yards and on main lines, were traced to abnormal amounts deposited during particular tests, but a study of the results did not show that any one test was the sole factor in producing the peaks in the diagram. One test, which was traced as having an influence on a seemingly abnormal percentage, was conducted in the open country when the velocity of the wind was 24 miles per hour.

Organic Matter not from Locomotives

The percentage of organic matter not from locomotives was found to be about the same for each pan location in switching yards in both zones. On main lines it was about the same for each pan location in both zones, except for pan location No. 10, in which the percentage in Zone A was much the larger. The mean percentage deposited in switching yards was highest at pan location No. 9, or 250 feet from the center of track, and lowest at pan No. 2, or 40 feet from the center of track. On main lines, it was highest at pan location No. 10, or 350 feet from the center of track, and lowest at pan No. 1, or 20 feet from the center of track.

THE PERFORMANCE OF ILLINOIS AND INDIANA COALS WHEN BURNED IN LOCOMOTIVE SERVICE

701.44 Description and Purposes of the Tests: For the purpose of establishing certain facts with reference to the smoke discharges of steam locomotives, the Committee conducted a series of tests upon a locomotive mounted on the locomotive testing plant of the Pennsylvania Railroad at Altoona, Pa. The facts established have been presented in connection with the Committee's study of smoke (chapter 105). During the progress of the tests, record was kept of data relating to the performance of the several samples of coal tested, and upon such data it has been possible to base a study of the performance of the different coals, first, in relation to smoke discharges, and second, in relation to boiler, engine and locomotive performance. The tests were planned also to show the following in connection with each sample tested:

1. The value of the brick arch in the locomotive fire-box as a factor promoting,
    a. Economy in the use of fuel.
    b. A reduction of cinders and fuel dust in smoke.
    c. A reduction of the density of visible smoke.
    d. Reduction of loss of heat units in the smoke and ash discharges.
    e. Boiler efficiency.
2. The value of experience in locomotive firing as a factor promoting,
    a. Economy of fuel consumption.
    b. A reduction of cinders and fuel dust in smoke.
    c. A reduction in the density of visible smoke.
    d. Boiler efficiency.

A total of 75 tests was made; in 56 the locomotive fire-box was equipped with a brick arch, and in 19 the brick arch was removed; 64 tests were made with experienced firemen and 11 were made with inexperienced firemen. The fire-box was equipped with a brick arch in 47 of the tests conducted with experienced firemen and in 9 of the tests made with inexperienced firemen. The experienced firemen were men who had had actual work on the road in firing the coals tested, or skilled firemen without such experience supervised by men who had had it. The inexperienced firemen were men whose records showed less than six months' work in firing a locomotive; they were permitted to fire according to their own judgment.

The results of the tests in which the locomotive fire-box was equipped with a brick arch show that the use of the brick arch in the fire-box gives:

1. An increase in evaporation and boiler efficiency.
2. A decrease in the amount of coal consumed per dynamometer horse-power-hour.
3. A decrease in the density of visible smoke emissions.
4. A decrease in the amount of cinders and fuel dust emitted in the smoke.
5. A decrease in the number of heat units lost in ash and clinker.
6. An increase in the volume of carbon dioxid, sulphur trioxid and sulphur dioxid in the gases emitted.
7. A decrease in the volume of carbon monoxid and oxygen in the gases emitted.

The tests in which the coal was fired by inexperienced firemen, when compared with those in which experienced firemen were employed, indicate that incorrect methods of firing result in:

1. An excess of fuel consumption per unit of power delivered.
2. A loss in boiler efficiency.
3. An increase in the density of visible smoke emissions.
4. An increase in the amount of cinders and fuel dust discharged in the smoke.
5. A loss in thermal efficiency.

The losses resulting from incorrect firing were shown to be much greater in the case of a locomotive equipped with a brick arch in the fire-box than in the case of one not so equipped.

701.45 Coals Selected for the Tests: The coals selected for this series of tests were representative of the coals burned in locomotives operating in the Chicago terminals. Fourteen of the railroads operating a very large portion of the locomotives in the Area of Investigation furnished information as to the amount of coal delivered to their locomotives during the year 1911, the location by town, county and state of the mine in which the coal originated, and the quantity delivered from each mine. Of the total amount of 3,640,301 tons so reported, the different sources of origin contributed the proportions indicated in the following:

	PER CENT
Illinois	63.55
Indiana	33.02
Ohio	1.46
Pennsylvania	0.33
Virginia and W. Va.	0.79
Other states	0.85
Total	100.00

Not all of the coal delivered to locomotives, as indicated by these reports, was consumed in the Area of Investigation, but it was assumed that the proportions indicated in the reports of coal delivered obtained also for the coal consumed. Of all the coal delivered, 96.57 per cent originated in Illinois and Indiana. For this reason, coal from these two states only was selected for the tests.

Of the coal from Illinois about 90 per cent originated in six counties, and of that from Indiana about 91 per cent came from four counties. The coals selected for test were therefore limited to coal from these ten counties. The coals tested thus included samples representative of approximately 88 per cent of all the coal consumed by locomotives in the Area of Investigation.

The following figures show the county of origin of the coals tested and the percentage that each county contributed to the total amount of coal delivered to the 14 railroads during the year 1911, for use in the Chicago terminals:

	PER CENT	
ILLINOIS		
Macoupin County	26.24	
Marion "	6.44	
Saline "	4.75	
Sangamon "	3.75	
Vermillion "	3.63	
Williamson "	12.15	
Total for test	56.96	
Other counties	6.59	
Total from Illinois		63.55
INDIANA		
Greene County	2.45	
Sullivan "	8.16	
Vermillion "	11.65	
Vigo "	8.47	
Total for test	30.73	
Other counties	2.29	
Total from Indiana		33.02
Total from Illinois and Indiana		96.57

One car of coal of about 50 tons from each of the ten counties was selected at random from cars delivered to the railroads at Chicago and shipped directly to the testing plant at Altoona. It was desired that each series of tests should be representative of the coal from a certain county, not from any particular mine or mines, and the name of the mine from which the coal was obtained was not known to the Committee. The person who made the selection was not informed of the purpose for which the coal was to be used.

701.46 Chemical Composition and Calorific Value of the Coals Tested: The chemical composition, as shown by proximate and ultimate analyses, and the calorific value of the coals tested are shown by table CDLXXXII.

It appears from table CDLXXXII that nine of the coals were nearly uniform in calorific value. The range of calorific values for these nine coals varied from 11,227 B. t. u. to 11,919 B. t. u., the average being 11,598 B. t. u. per pound of coal. The coal from one county had a calorific value of 13,247 B. t. u. per pound, or 14.22 per cent more than the average for the other nine coals.

701.47 Observed Data and Average Results of Tests: The data recorded in connection with the tests, and the results of the tests as to boiler, engine and locomotive performance and smoke discharges, are presented as tables CDLXXXIII to CDLXXXIX, inclusive.

Based upon the data obtained from the tests as presented by tables CDLXXXIII to CDLXXXIX, inclusive, a study has been made of the relative performance of the several test coals used. The facts thus developed are set forth in the sections which follow.

701.48 Evaporative Values of the Coals Tested: The actual test results for equivalent evaporation per pound of fuel burned, as presented in table CDLXXXIII, were plotted in terms of rates of combustion, and a smooth curve was drawn through the points thus located. Values were taken from this curve for each of the ten samples of coal when burned in a locomotive fire-box equipped with a brick arch, and for each of four samples when burned in a locomotive fire-box not equipped with a brick arch. These values, and also a comparison of the results obtained from the same coals when burned with and without the brick arch, are presented as table CDXC.

For purposes of comparison, the results of the tests as given in table CDXC are separated into groups. Group BA-10 shows results of tests of ten coals when burned in a locomotive fire-box equipped with a brick arch; group NA-4, the results of tests of four of the coals most extensively used in Chicago terminals when burned in a locomotive fire-box not equipped with a brick arch; and group BA-4, the results of tests of the same four coals when burned in a fire-box with a brick arch, as taken from the results given in group BA-10.

The last column of table CDXC presents a record of the relative evaporative value of the several coals, based upon the average value for all coals taken as 100.

The values presented by the table were based upon rates of evaporation, the range of performance varying

TABLE CDLXXXII. CHEMICAL COMPOSITION AND CALORIFIC VALUE OF COALS TESTED AT ALTOONA, PA.

County of Origin	B. t. u. by Calorimeter	Total Moisture*	Proximate Analysis Air Dried Samples				Ultimate Analysis					Oxygen by Difference
			Moisture	Volatile	Fixed Carbon	Ash	Carbon	Hydrogen	Nitrogen	Sulphur	Ash	
		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13
Macoupin (Ill.)	11,358	11.40	10.49	40.56	40.46	8.49	63.11	5.44	1.04	4.09	8.49	17.83
Marion (Ill.)	11,227	10.56	8.73	37.81	40.33	13.13	62.41	5.15	1.09	2.88	13.13	15.34
Saline (Ill.)	13,247	4.62	3.87	38.61	50.74	6.78	73.59	5.17	1.51	2.35	6.78	10.60
Sangamon (Ill.)	11,261	12.86	10.74	40.75	38.10	10.41	62.51	5.53	1.07	3.65	10.41	16.83
Vermillion (Ill.)	11,527	12.20	8.13	39.37	41.43	11.07	63.93	5.20	1.33	2.82	11.07	15.65
Williamson (Ill.)	11,888	7.95	6.88	35.96	47.10	10.06	67.85	5.00	1.32	0.71	10.06	15.06
Greene (Ind.)	11,919	11.33	8.69	38.13	43.28	9.90	66.10	5.30	1.31	2.80	9.90	14.59
Sullivan (Ind.)	11,835	10.84	7.56	40.92	40.17	11.35	64.85	5.45	1.16	3.37	11.35	13.82
Vermillion (Ind.)	11,561	9.31	6.23	42.02	37.98	13.77	62.89	5.34	1.16	4.43	13.77	12.41
Vigo (Ind.)	11,807	7.95	4.42	41.50	41.08	13.00	63.76	5.24	1.24	4.93	13.00	11.83
Total percentage			100				100					

* In coal as taken from the car.

TABLE CDLXXXIII. TABULATION OF AVERAGE RESULTS OF TESTS OF REPRESENTATIVE ILLINOIS AND INDIANA COALS MADE IN THE LOCOMOTIVE TESTING PLANT OF THE PENNSYLVANIA RAILROAD AT ALTOONA, PA. (PENNSYLVANIA LOCOMOTIVE, TYPE 2 8 0, CLASS H 8 b, No. 1134)

Test Number	Date of Report	County of Origin	R.P.M.	Approx. Cut-Off Per Cent	Throttle Opening	Duration Hours	Miles per Hour	Actual Cut-Off Per Cent	Brick Arch	Avg. Boiler Pressure, Lb. per Sq. In.	Smoke-Box Ins. of Water	Ash-Pan Ins. of Water	Calorific Value B.t.u. per Lb.	Fired per Hour, Lb.	Fired per Hour Lb. per Sq. Ft. Grate	Water Del'd to Boiler, Lb per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Surface	Per Lb. Dry Fuel	Boiler-Horse-Power (34½ U. of E.)	Efficiency of Boiler Based on Fuel	Avg. Smoke Density Per Cent
			Running Conditions							Boiler Performance												
											Draft		Dry Fuel				Equivalent Evaporation from and at 212° F., Lb.					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
2715	8-27-12	Macoupin (Ill.)	40	20	Full	2.0	7.33	19.1	No	203.9	1.4	0.05	12,689	1,277	23.7	10,406	12,447	3.7	9.8	360.8	74.6	24
2716			80	25	"	2.0	14.66	25.6	"	199.5	3.3	0.10	"	2,892	53.7	19,573	23,418	6.9	8.1	678.8	62.0	30
2717			80	35	"	2.0	14.66	38.5	"	205.2	6.0	0.17	"	4,316	80.1	27,506	33,026	9.7	7.7	957.3	58.6	38
2718			100	42	"	0.5	18.33	45.4	"	183.5	8.2	0.21	"	4,936	91.6	33,772	40,468	11.9	8.2	1173.0	62.7	42
*2719			80	25	"	2.0	14.66	....	"	198.7	3.7	0.08	"	3,428	63.6	19,286	23,112	6.8	6.7	669.9	51.5	42
2720			40	20	"	2.0	7.33	....	Yes	203.9	1.6	0.04	"	1,348	25.0	10,947	13,010	3.8	9.7	377.1	73.8	18
2721			80	25	"	2.0	14.66	....	"	205.5	3.5	0.10	"	2,658	49.3	20,066	24,016	7.1	9.0	696.1	69.1	20
2722			80	35	"	2.0	14.66	....	"	205.0	6.3	0.12	"	3,987	74.0	27,606	33,168	9.8	8.3	961.4	63.6	24
2723			100	42	"	1.0	18.33	44.1	"	198.1	8.9	0.16	"	5,942	110.2	35,703	42,870	12.6	7.2	1242.6	55.1	42
2724			120	42	"	0.5	22.00	40.9	"	179.8	9.5	0.12	"	5,774	107.1	35,932	43,121	12.7	7.5	1249.9	57.1	40
2796	10-24-12	Marion (Ill.)	40	20	"	2.0	7.33	....	"	203.5	1.9	0.04	12,553	1,703	31.6	12,384	14,768	4.3	8.7	428.1	67.0	24
2797			80	25	"	2.0	14.66	....	"	192.3	3.4	0.08	"	2,567	47.6	18,856	22,090	6.7	8.8	657.7	68.3	14
2798			80	35	"	2.0	14.66	....	"	195.1	6.0	0.13	"	4,472	83.0	26,605	32,103	9.4	7.2	930.5	55.5	26
2799			80	25	"	2.0	14.66	....	"	205.0	3.9	0.08	"	2,749	51.0	20,003	24,120	7.1	8.8	699.1	67.8	14
*2700			80	25	"	2.0	14.66	....	"	184.1	3.1	0.07	"	3,413	63.3	17,697	21,350	6.3	6.3	618.8	48.4	30
2790	10-24-12	Saline (Ill.)	40	20	"	2.0	7.33	....	"	203.5	1.7	0.04	13,889	1,459	27.1	12,981	15,606	4.6	10.7	452.3	74.8	28
2791			80	25	"	2.0	14.66	....	"	206.0	3.9	0.06	"	2,341	43.4	20,116	24,241	7.1	10.4	702.6	72.3	24
2792			80	35	"	2.0	14.66	....	"	204.3	6.4	0.14	"	3,456	64.1	27,446	33,156	9.7	9.6	961.0	67.0	30
2793			100	42	"	1.0	18.33	....	"	204.9	10.8	0.16	"	6,255	116.1	37,215	44,976	13.2	7.2	1303.7	50.2	64
2794			120	42	"	0.5	22.00	....	"	177.0	10.1	0.18	"	6,020	111.7	35,862	43,319	12.7	7.2	1255.6	50.3	78
*2795			80	25	"	2.0	14.66	....	"	204.3	3.8	0.07	"	3,464	64.3	21,413	25,844	7.6	7.5	749.1	52.1	64
2732	9-3-12	Sangamon (Ill.)	40	20	"	2.0	7.33	....	"	202.3	1.6	0.04	12,616	1,416	26.3	11,090	13,145	3.9	9.3	381.0	71.4	20
2733			80	25	"	2.0	14.66	....	"	205.1	3.8	0.09	"	2,570	47.7	20,039	23,968	7.0	9.3	694.7	71.8	18
2734			80	35	"	2.0	14.66	....	"	204.1	6.4	0.15	"	3,723	69.1	28,126	33,742	9.9	9.1	978.0	69.7	22
2735			100	42	"	1.0	18.33	....	"	197.1	10.4	0.21	"	5,690	105.6	36,228	43,432	12.8	7.6	1258.9	58.7	30
2736			120	42	"	0.5	22.00	....	"	183.0	10.4	0.20	"	5,906	109.6	35,532	42,605	12.5	7.2	1234.9	55.5	42
*2737			80	25	"	1.0	14.66	....	"	142.6	2.2	0.03	"	2,516	46.7	16,436	19,561	5.8	7.8	567.0	59.8	52
2748	9-30-12	Vermillion (Ill.)	40	20	"	2.0	7.33	....	"	201.5	1.7	0.03	12,547	1,317	24.4	11,775	14,074	4.1	10.7	407.9	82.7	22
2749			80	25	"	2.0	14.66	....	"	204.2	3.6	0.07	"	2,531	47.0	20,279	24,301	7.1	9.6	704.4	74.3	22
2750			80	35	"	2.0	14.66	....	"	203.0	5.8	0.11	"	3,433	63.7	26,615	31,971	9.4	9.3	926.7	72.0	22
2751			100	42	"	1.0	18.33	....	"	203.1	10.2	0.21	"	5,660	105.0	37,262	44,821	13.2	7.9	1299.2	61.3	26
2752			120	42	"	0.75	22.00	....	"	190.2	10.5	0.19	"	6,611	122.7	36,987	44,456	13.1	6.7	1288.6	52.0	50
*2753			80	25	"	2.0	14.66	....	"	204.5	4.0	0.07	"	3,273	60.7	22,260	26,747	7.9	8.2	775.3	63.2	34
2725	8-30-12	Williamson (Ill.)	40	20	"	2.0	7.33	....	No	204.3	1.6	0.05	12,766	1,381	25.6	11,713	14,011	4.1	10.2	406.1	77.2	18
2726			80	25	"	2.0	14.66	....	"	205.8	3.2	0.09	"	2,652	49.2	19,864	23,827	7.0	9.0	690.6	68.3	24
2727			80	35	"	2.0	14.66	....	"	205.9	6.1	0.16	"	4,143	76.9	27,841	33,514	9.9	8.1	971.4	61.6	24
2728			100	42	"	1.0	18.33	....	"	193.3	9.0	0.21	"	5,670	105.2	35,905	43,163	12.7	7.6	1251.1	57.9	32
2729			120	42	"	0.25	22.00	....	"	161.3	8.2	0.16	"	7,364	136.6	32,240	38,699	11.4	5.3	1121.7	40.0	70
*2730			80	25	"	2.0	14.66	....	"	205.4	3.7	0.08	"	2,563	47.6	20,741	24,913	7.3	9.7	722.1	73.9	20
2738			40	20	"	2.0	7.33	....	Yes	203.4	1.7	0.04	"	1,381	25.6	11,903	14,193	4.2	10.3	411.4	78.1	12
2739			80	25	"	2.0	14.66	....	"	204.5	3.8	0.07	"	2,551	47.3	21,437	25,657	7.5	10.1	743.7	76.5	14
2740			80	35	"	2.0	14.66	....	"	203.4	6.6	0.13	"	3,682	68.3	28,371	34,065	10.0	9.3	987.4	70.3	18
2741			100	42	"	1.0	18.33	....	"	182.7	9.8	0.19	"	5,523	102.5	34,431	41,250	12.1	7.5	1195.7	56.8	32
*2742	9-6-12		80	25	"	2.0	14.66	....	"	204.8	3.9	0.07	"	2,892	53.7	21,729	26,015	7.6	9.0	754.1	68.4	16
2743	9-11-12	Greene (Ind.)	40	20	"	2.0	7.33	....	"	203.8	1.7	0.03	13,053	1,330	24.7	11,929	14,238	4.2	10.7	412.7	79.6	22
2744			80	25	"	2.0	14.66	....	"	206.0	4.0	0.07	"	2,334	43.3	20,526	24,584	7.2	10.5	712.6	78.3	8
2745			80	35	"	2.0	14.66	....	"	203.4	6.2	0.17	"	3,189	59.2	27,126	32,451	9.5	10.2	940.6	75.7	16
2746			100	42	"	1.0	18.33	....	"	187.0	9.9	0.24	"	4,967	92.2	35,013	42,007	12.3	8.5	1217.6	62.9	26
*2747			80	25	"	2.0	14.66	....	"	204.3	3.7	0.10	"	2,856	53.0	20,521	24,512	7.2	8.6	710.5	63.8	26
2780	10-24-12	Sullivan (Ind.)	40	20	"	2.0	7.33	....	"	202.7	1.8	0.04	13,274	1,461	27.1	12,033	14,423	4.2	9.9	418.1	72.2	28
2781			80	25	"	2.0	14.66	....	"	203.2	3.7	0.08	"	2,478	46.0	19,757	23,694	7.0	9.6	686.8	69.9	28
2782			80	35	"	2.0	14.66	....	"	204.1	7.5	0.13	"	3,567	66.2	27,599	33,251	9.8	9.3	963.8	68.1	24
2783			100	42	"	1.0	18.33	....	"	194.6	10.2	0.20	"	5,350	99.3	35,723	43,344	12.7	8.1	1256.3	59.2	38
2784			120	42	"	0.5	22.00	....	"	189.5	11.1	0.18	"	7,132	132.3	37,210	44,677	13.2	6.3	1300.8	46.0	70
*2785			80	25	"	2.0	14.66	....	"	203.2	4.2	0.09	"	3,652	67.8	21,367	25,754	7.6	7.1	746.5	51.5	52
2786			40	20	"	2.0	7.33	....	No	202.1	2.0	0.05	"	1,612	29.9	12,536	15,066	4.4	9.4	436.7	68.4	44
2787			80	25	"	2.0	14.66	....	"	202.8	3.4	0.08	"	2,524	46.8	19,676	23,695	7.0	9.4	686.8	68.7	46
2788			80	35	"	2.0	14.66	....	"	201.8	6.0	0.13	"	4,159	77.2	27,516	33,230	9.8	8.0	963.2	58.4	52
2789			100	42	"	1.0	18.33	....	"	175.3	7.8	0.22	"	5,017	93.1	31,623	38,132	11.2	7.6	1105.3	55.6	62

* Fired by an inexperienced fireman.

TABLE CDLXXXIII (Continued). TABULATION OF AVERAGE RESULTS OF TESTS OF REPRESENTATIVE ILLINOIS AND INDIANA COALS MADE IN THE LOCOMOTIVE TESTING PLANT OF THE PENNSYLVANIA RAILROAD AT ALTOONA, PA. (PENNSYLVANIA LOCOMOTIVE, TYPE 2-8-B; CLASS H-8-6; No. 1134)

Test Number	Date of Report	County of Origin	Running Conditions							Boiler Performance												
											Draft		Dry Fuel				Equivalent Evaporation from and at 212° F., Lb.					
			R.P.M.	Approx. Cut-Off Per Cent	Throttle Opening	Duration Hours	Miles per Hour	Actual Cut-Off Per Cent	Brick Arch	Avg. Boiler Pressure, Lb. per Sq. In.	Smoke-Box Ins. of Water	Ash-Pan Ins. of Water	Calorific Value B.t.u. per Lb.	Fired per Hour, Lb.	Fired per Hour Lb. per Sq. Ft. Grate	Water Del'd to Boiler, Lb. per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Surface	Per Lb. Dry Fuel	Boiler-Horse-Power (34½ U. of E.)	Efficiency of Boiler Based on Fuel	Avg. Smoke Density Per Cent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
2760	10-24-12	Vermillion (Ind.)	40	20	Full	2.0	7.33	....	Yes	202.5	1.8	0.05	12,748	1,461	27.1	11,850	14,163	4.2	9.7	410.5	73.8	28
2761			80	25	"	2.0	14.66	....	"	205.4	3.9	0.08	"	2,469	45.8	20,437	24,483	7.2	9.9	709.7	75.5	16
2762			80	35	"	2.0	14.66	....	"	204.0	6.4	0.19	"	3,715	68.9	27,135	32,578	9.6	8.8	944.3	66.8	20
2763			100	42	"	1.0	18.33	....	"	196.6	10.2	0.24	"	5,626	104.4	35,478	42,594	12.5	7.6	1234.6	57.6	34
2764			120	42	"	0.25	22.00	....	"	176.3	9.6	0.23	"	6,216	115.3	35,640	42,759	12.6	6.9	1239.4	52.4	48
*2765			80	25	"	2.0	14.66	....	"	203.2	4.1	0.10	"	3,027	56.2	21,267	25,501	7.5	8.4	739.2	64.1	28
2766			40	20	"	2.0	7.33	....	No	202.3	1.5	0.04	"	1,467	27.2	11,800	14,116	4.2	9.6	409.2	73.2	40
2767			80	25	"	2.0	14.66	....	"	204.5	3.9	0.10	"	2,721	50.5	20,871	25,045	7.4	9.2	725.9	70.0	26
2768			80	35	"	2.0	14.66	....	"	202.8	5.7	0.17	"	4,081	75.7	26,913	32,365	9.5	7.9	938.9	60.4	42
2769			100	42	"	1.0	18.33	....	"	174.9	8.0	0.20	"	5,441	101.0	31,316	37,516	11.0	6.9	1087.4	52.5	48
2754	10-24-12	Vigo (Ind.)	40	20	"	2.0	7.33	....	Yes	203.6	1.6	0.04	12,827	1,433	26.6	11,868	14,191	4.2	9.9	411.3	74.9	24
2755			80	25	"	2.0	14.66	....	"	204.5	3.4	0.08	"	2,522	46.8	19,891	23,852	7.0	9.5	691.4	71.6	20
2756			80	35	"	2.0	14.66	....	"	204.1	6.4	0.17	"	3,810	70.7	27,491	32,928	9.7	8.6	954.4	65.4	22
2757			100	42	"	1.0	18.33	....	"	203.7	10.7	0.25	"	6,229	115.6	38,040	45,669	13.4	7.3	1323.7	55.5	34
2758			120	42	"	0.5	22.00	....	"	187.5	10.6	0.23	"	7,364	136.6	37,376	44,786	13.2	6.1	1298.1	46.0	58
*2759			80	25	"	2.0	14.66	....	"	203.8	3.8	0.10	"	2,788	51.7	20,404	24,462	7.2	8.8	709.0	66.4	22

* Fired by an inexperienced fireman.

TABLE CDLXXXIV. TABULATION OF AVERAGE RESULTS OF TESTS OF REPRESENTATIVE ILLINOIS AND INDIANA COALS MADE IN THE LOCOMOTIVE TESTING PLANT OF THE PENNSYLVANIA RAILROAD AT ALTOONA, PA. (PENNSYLVANIA LOCOMOTIVE. TYPE 2-8-B; CLASS H-8-6; No. 1134)

			Running Conditions							Engine Performance				Locomotive Performance							
Test Number	Date of Report	County of Origin	R.P.M.	Approx. Cut-Off Per Cent	Throttle Opening	Duration Hours	Miles per Hour	Actual Cut-Off Per Cent	Brick Arch	Dry Steam to Engines Lb. per Hour	I.H.P.	Dry Fuel per I.H.P. Hour, Lb.	Dry Steam per I.H.P. Hour, Lb.	Drawbar Pull, Lb.	Dynamometer or Drawbar H. P.	Dry Fuel per Dynamometer H. P. Hour, Lb.	Dry Steam per Dynamometer H. P. Hour, Lb.	Machine Efficiency of Loco. Per Cent	Thermal Efficiency of Loco. Per Cent Based on Fuel	Dry Sparks Discharged from Stack Per Cent of Total Fuel as Fired	Test Number
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
2715	8-27-12	Macoupin (Ill.)	40	20	Full	2.0	7.33	19.1	No	10,441	362.8	3.5	28.8	14,463	282.8	4.5	36.9	78.0	4.4	2.31	2715
2716			80	25	"	2.0	14.66	25.6	"	19,520	759.8	3.8	25.7	16,788	656.5	4.4	29.7	86.4	4.6	2.56	2716
2717			80	35	"	2.0	14.66	38.5	"	27,462	1054.0	4.1	26.1	23,905	934.8	4.6	29.4	88.7	4.3	5.16	2717
2718			100	42	"	0.5	18.33	45.4	"	33,715	1173.6	4.2	28.7	23,448	1146.1	4.3	29.4	97.7	4.7	6.71	2718
*2719			80	25	"	2.0	14.66	....	"	19,162	.....	...	....	16,194	633.3	5.4	30.3	....	3.7	2.57	*2719
2720			40	20	"	2.0	7.33	....	Yes	10,921	.....	...	....	14,691	287.2	4.7	38.0	....	4.3	2.52	2720
2721			80	25	"	2.0	14.66	....	"	19,982	.....	...	....	16,922	661.7	4.0	30.2	....	5.0	2.17	2721
2722			80	35	"	2.0	14.66	....	"	27,229	.....	...	....	23,674	925.7	4.3	29.4	....	4.7	4.18	2722
2723			100	42	"	1.0	18.33	44.1	"	35,594	1353.2	4.4	26.3	24,220	1183.9	5.0	30.1	87.5	4.0	7.64	2723
2724			120	42	"	0.5	22.00	40.9	"	35,871	1349.3	4.3	26.6	20,354	1193.9	4.8	30.1	88.5	4.1		2724
2796	10-24-12	Marion (Ill.)	40	20	"	2.0	7.33	....	"	11,777	.....	...	....	14,925	291.8	5.8	40.4	....	3.5	2.98	2796
2797			80	25	"	2.0	14.66	....	"	18,805	.....	...	....	14,873	581.6	4.4	32.3	....	4.6	3.82	2797
2798			80	35	"	2.0	14.66	....	"	26,005	.....	...	....	21,548	842.6	5.3	30.9	....	3.8	6.24	2798
2799			80	25	"	2.0	14.66	....	"	19,829	.....	...	....	16,011	626.1	4.4	31.7	....	4.6	2.57	2799
*2700			80	25	"	2.0	14.66	....	"	17,324	.....	...	....	13,718	536.4	6.4	32.3	....	3.2	2.68	*2700
2790	10-24-12	Saline (Ill.)	40	20	"	2.0	7.33	....	"	11,777	.....	...	....	14,514	283.8	5.1	41.5	....	3.6	2.10	2790
2791			80	25	"	2.0	14.66	....	"	19,784	.....	...	....	16,014	626.2	3.7	31.6	....	4.9	1.84	2791
2792			80	35	"	2.0	14.66	....	"	27,173	.....	...	....	22,566	882.4	3.9	30.8	....	4.7	4.56	2792
2793			100	42	"	1.0	18.33	....	"	37,029	.....	...	....	24,628	1203.9	5.2	30.8	....	3.5	6.81	2793
2794			120	42	"	0.5	22.00	....	"	35,801	.....	...	....	20,083	1178.0	5.1	30.4	....	3.6		2794
*2795			80	25	"	2.0	14.66	....	"	19,793	.....	...	....	16,316	638.0	5.4	31.0	....	3.4	4.10	*2795
2732	9-3-12	Sangamon (Ill.)	40	20	"	2.0	7.33	....	"	10,956	.....	...	....	14,376	281.1	5.0	39.0	....	4.0	3.09	2732
2733			80	25	"	2.0	14.66	....	"	19,985	.....	...	....	16,846	658.7	3.9	30.3	....	5.2	1.92	2733
2734			80	35	"	2.0	14.66	....	"	27,747	.....	...	....	23,405	915.2	4.1	30.3	....	5.0	3.13	2734
2735			100	42	"	1.0	18.33	....	"	36,083	.....	...	....	24,099	1178.0	4.8	30.6	....	4.2	6.39	2735
2736			120	42	"	0.5	22.00	....	"	35,472	.....	...	....	20,379	1195.4	4.9	29.7	....	4.1		2736
*2737			80	25	"	1.0	14.66	....	"	16,392	.....	...	....	10,736	419.8	6.0	39.1	....	3.4	3.76	*2737
2748	9-30-12	Vermillion (Ill.)	40	20	"	2.0	7.33	....	"	11,032	.....	...	....	14,171	277.1	4.8	39.8	....	4.3	2.44	2748
2749			80	25	"	2.0	14.66	....	"	20,073	.....	...	....	16,102	629.7	4.0	31.9	....	5.1	2.88	2749
2750			80	35	"	2.0	14.66	....	"	26,357	.....	...	....	22,654	885.9	3.9	29.8	....	5.2	3.90	2750
2751			100	42	"	1.0	18.33	....	"	37,136	.....	...	....	24,872	1215.7	4.7	30.6	....	4.4	8.94	2751
2752			120	42	"	0.75	22.00	....	"	36,924	.....	...	....	21,050	1234.7	5.4	29.9	....	3.8		2752
*2753			80	25	"	2.0	14.66	....	"	19,954	.....	...	....	16,503	645.3	5.1	30.9	....	4.0	2.26	*2753
2725	8-30-12	Williamson (Ill.)	40	20	"	2.0	7.33	....	No	11,539	.....	...	....	15,300	299.1	4.6	38.6	....	4.3	3.11	2725
2726			80	25	"	2.0	14.66	....	"	19,724	.....	...	....	16,270	636.2	4.2	31.0	....	4.8	2.18	2726
2727			80	35	"	2.0	14.66	....	"	27,796	.....	...	....	23,324	912.1	4.5	30.5	....	4.4	6.94	2727
2728			100	42	"	1.0	18.33	....	"	35,844	.....	...	....	23,564	1151.8	4.9	31.1	....	4.1	10.68	2728
2729			120	42	"	0.25	22.00	....	"	32,185	.....	...	....	17,915	1050.8	7.0	30.6	....	2.8		2729
*2730			80	25	"	2.0	14.66	....	"	20,347	.....	...	....	17,159	671.0	3.8	30.3	....	5.2	3.39	*2730
2738			40	20	"	2.0	7.33	....	Yes	11,743	.....	...	....	14,679	287.0	4.8	40.9	....	4.1	2.81	2738
2739			80	25	"	2.0	44.66	....	"	21,128	.....	...	....	16,811	657.4	3.9	32.1	....	5.1	2.74	2739
2740			80	35	"	2.0	14.66	....	"	28,132	.....	...	....	22,962	897.9	4.1	31.3	....	4.9	1.91	2740
2741			100	42	"	1.0	18.33	....	"	34,372	.....	...	....	22,420	1095.9	5.0	31.4	....	4.0	2.36	2741
*2742	9-6-12		80	25	"	2.0	14.66	....	"	20,178	.....	...	....	16,834	658.3	4.4	30.7	....	4.5	4.12	*2742
2743	9-11-12	Greene (Ind.)	40	20	"	2.0	7.33	....	"	11,532	.....	...	....	15,044	294.1	4.5	39.2	....	4.3	2.23	2743
2744			80	25	"	2.0	14.66	....	"	20,394	.....	...	....	16,705	653.2	3.6	31.2	....	5.3	7.89	2744
2745			80	35	"	2.0	14.66	....	"	26,918	.....	...	....	23,058	901.7	3.5	29.9	....	5.5	6.44	2745
2746			100	42	"	1.0	18.33	....	"	34,953	.....	...	....	23,841	1165.3	4.3	30.0	....	4.6	10.15	2746
*2747			80	25	"	2.0	14.66	....	"	19,795	.....	...	....	16,026	626.7	4.6	31.6	....	4.3	5.38	*2747
2780	10-24-12	Sullivan (Ind.)	40	20	"	2.0	7.33	....	"	11,500	.....	...	....	13,913	272.0	5.4	42.6	....	3.6	3.12	2780
2781			80	25	"	2.0	14.66	....	"	19,704	.....	...	....	15,344	607.8	4.1	32.4	....	4.7	2.61	2781
2782			80	35	"	2.0	14.66	....	"	27,183	.....	...	....	22,760	890.4	5.0	30.5	....	4.8	4.21	2782
2783			100	42	"	1.0	18.33	....	"	35,602	.....	...	....	23,391	1143.4	4.7	31.1	....	4.1	7.40	2783
2784			120	42	"	0.5	22.00	....	"	37,147	.....	...	....	20,926	1227.4	5.8	30.3	....	3.3		2784
*2785			80	25	"	2.0	14.66	....	"	20,143	.....	...	....	16,255	635.6	5.8	31.7	....	3.3	2.71	*2785
2786			40	20	"	2.0	7.33	....	No	12,162	.....	...	....	15,246	298.1	5.4	40.8	....	3.5	3.37	2786
2787			80	25	"	2.0	14.66	....	"	19,623	.....	...	....	15,540	606.5	4.2	32.4	....	4.6	2.53	2787
2788			80	35	"	2.0	14.66	....	"	27,166	.....	...	....	22,601	883.8	4.7	30.7	....	4.1	4.91	2788
2789			100	42	"	1.0	18.33	....	"	31,560	.....	...	....	20,438	999.0	5.0	31.6	....	3.8	13.93	2789

* Fired by an inexperienced fireman.

TABLE CDLXXXIV (Continued). TABULATION OF AVERAGE RESULTS OF TESTS OF REPRESENTATIVE ILLINOIS AND INDIANA COALS MADE IN THE LOCOMOTIVE TESTING PLANT OF THE PENNSYLVANIA RAILROAD AT ALTOONA, PA. (PENNSYLVANIA LOCOMOTIVE, TYPE 2-8-B; CLASS H-8-6; No. 1134)

			Running Conditions							Engine Performance				Locomotive Performance							
Test Number	Date of Report	County of Origin	R.P.M.	Approx. Cut-Off Per Cent	Throttle Opening	Duration Hours	Miles per Hour	Actual Cut-Off Per Cent	Brick Arch	Dry Steam to Engines Lb. per Hour	I.H.P.	Dry Fuel per I.H.P. Hour, Lb.	Dry Steam per I.H.P. Hour, Lb.	Drawbar Pull, Lb.	Dynamometer or Drawbar H. P.	Dry Fuel per Dynamometer H.P. Hour Lb.	Dry Steam per Dynamometer H.P. Hour Lb.	Machine Efficiency of Loco. Per Cent	Thermal Efficiency of Loco. Per Cent Based on Fuel	Dry Sparks Discharged from Stack Per Cent of Total Fuel as Fired	Test Number
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
2760	10-24-12	Vermillion (Ind.)	40	20	Full	2.0	7.33	....	Yes	11,585	.....	...	....	15,739	307.7	4.8	37.7	....	4.2	6.94	2760
2761			80	25	"	2.0	14.66	....	"	20,343	.....	...	....	16,701	653.1	3.8	31.2	....	5.3	3.06	2761
2762			80	35	"	2.0	14.66	....	"	27,092	.....	...	....	23,182	906.5	4.1	29.9	....	4.9	4.75	2762
2763			100	42	"	1.0	18.33	....	"	35,418	.....	...	....	24,330	1189.3	4.7	29.8	....	4.2	10.01	2763
2764			120	42	"	0.25	22.00	....	"	35,579	.....	...	....	19,851	1164.4	5.3	30.6	....	3.7		2764
*2765			80	25	"	2.0	14.66	....	"	21,066	.....	...	....	17,148	670.6	4.5	31.4	....	4.4	5.37	*2765
2766			40	20	"	2.0	7.33	....	No	11,296	.....	...	....	14,891	291.1	5.0	38.8	....	4.0	1.73	2766
2767			80	25	"	2.0	14.66	....	"	20,716	.....	...	....	16,689	652.6	4.2	31.7	....	4.8	3.54	2767
2768			80	35	"	2.0	14.66	....	"	26,816	.....	...	....	22,808	891.9	4.6	30.1	....	4.4	7.09	2768
2769			100	42	"	1.0	18.33	....	"	31,212	.....	...	....	20,815	1017.4	5.4	30.7	....	3.7	12.85	2769
2754	10-24-12	Vigo (Ind.)	40	20	"	2.0	7.33	....	Yes	11,492	.....	...	....	14,113	275.9	5.2	41.7	....	3.8	2.05	2754
2755			80	25	"	2.0	14.66	....	"	19,518	.....	...	....	16,068	628.3	4.0	31.1	....	5.0	4.21	2755
2756			80	35	"	2.0	14.66	....	"	27,264	.....	...	....	23,043	901.1	4.2	30.3	....	4.7	4.50	2756
2757			100	42	"	1.0	18.33	....	"	37,915	.....	...	....	25,144	1229.0	5.1	30.9	....	3.9	6.07	2757
2758			120	42	"	0.5	22.00	....	"	37,312	.....	...	....	21,363	1253.1	5.9	29.8	....	3.4		2758
*2759			80	25	"	2.0	14.66	....	"	20,190	.....	...	....	16,735	654.4	4.3	30.9	....	4.7	5.66	*2759

* Fired by an inexperienced fireman.

TABLE CDLXXXV. PHYSICAL AND CHEMICAL COMPOSITION OF SOLID MATERIALS IN LOCOMOTIVE SMOKE AS DETERMINED BY ANALYSIS OF THE DISCHARGE FROM A LOCOMOTIVE SMOKE STACK

(Tests made at Altoona, Pa.)

Test Number	County of Origin	R. P. M.	Miles per Hour	Brick Arch	Comparison of Fuel as Fired (By Weight) and Solid Constituents of Smoke (By Weight—Pounds)								
					Per Cent of Fuel Fired								
					Physical Classification				Chemical Classification				
					Coarse Cinders	Fine Cinders	Fuel Dust	Total Cinders and Dust	Hydro-Carbons (Tar)	Combustible Solids (Carbon)	Mineral Matter (Ash)	Sulphur	Total Chemical Components
1	2	3	4	5	6	7	8	9	10	11	12	13	14
2715	Macoupin (Ill.)	40	7.33	No	0.289	1.696	0.320	2.305	0.005	1.525	0.716	0.059	2.305
2716		80	14.66	"	0.748	1.536	0.276	2.560	0.002	1.382	1.118	0.058	2.560
2717		80	14.66	"	1.820	2.984	0.354	5.158	0.008	3.777	1.234	0.139	5.158
2718		100	18.33	"	2.615	3.770	0.326	6.711	0.011	5.172	1.344	0.184	6.711
*2719		80	14.66	"	0.665	1.747	0.159	2.571	0.011	1.761	0.728	0.071	2.571
2720		40	7.33	Yes	0.476	1.878	0.162	2.516	0.039	1.757	0.635	0.085	2.516
2721		80	14.66	"	0.452	1.447	0.266	2.165	0.006	1.259	0.840	0.060	2.165
2722		80	14.66	"	1.696	2.196	0.286	4.178	0.011	2.940	1.183	0.044	4.178
2723		100	18.33	"	2.778	4.057	0.803	7.638	0.011	6.071	1.331	0.225	7.638
2724		120	22.00										
2796	Marion (Ill.)	40	7.33	"	0.557	1.861	0.557	2.975	0.007	1.809	1.072	0.087	2.975
2797		80	14.66	"	1.300	2.159	0.363	3.822	0.014	2.065	1.657	0.086	3.822
2798		80	14.66	"	2.606	2.620	1.013	6.239	0.016	4.327	1.661	0.235	6.239
2799		80	14.66	"	0.534	1.846	0.185	2.565	0.009	1.477	0.975	0.104	2.565
*2700		80	14.66	"	1.012	1.082	0.585	2.679	0.012	1.748	0.862	0.057	2.679
2790	Saline (Ill.)	40	7.33	"	0.344	1.454	0.302	2.100	0.012	1.361	0.677	0.050	2.100
2791		80	14.66	"	0.351	1.227	0.262	1.840	0.009	1.230	0.574	0.027	1.840
2792		80	14.66	"	0.991	3.072	0.495	4.558	0.011	3.362	1.120	0.065	4.558
2793		100	18.33	"	2.024	4.047	0.740	6.811	0.022	5.267	1.409	0.113	6.811
2794		120	22.00										
*2795		80	14.66	"	1.288	2.344	0.474	4.104	0.009	3.069	0.958	0.068	4.104
2732	Sangamon (Ill.)	40	7.33	"	0.446	2.029	0.618	3.093	0.021	1.443	1.546	0.083	3.093
2733		80	14.66	"	0.446	1.211	0.264	1.921	0.011	1.049	0.804	0.057	1.921
2734		80	14.66	"	0.448	2.235	0.448	3.131	0.017	1.875	1.144	0.096	3.131
2735		100	18.33	"	3.028	2.949	0.414	6.391	0.009	4.863	1.470	0.049	6.391
2736		120	22.00										
*2737		80	14.66	"	0.514	2.838	0.406	3.758	0.016	2.315	1.293	0.134	3.758
2748	Vermillion (Ill.)	40	7.33	"	0.362	1.564	0.515	2.441	0.028	1.412	0.880	0.121	2.441
2749		80	14.66	"	0.616	1.889	0.378	2.883	0.005	1.754	1.071	0.053	2.883
2750		80	14.66	"	1.859	1.757	0.288	3.904	0.011	2.376	1.436	0.081	3.904
2751		100	18.33	"	2.802	5.376	0.766	8.944	0.003	7.079	1.724	0.138	8.944
2752		120	22.00										
*2753		80	14.66	"	0.553	1.472	0.237	2.262	0.001	1.574	0.650	0.037	2.262
2725	Williamson (Ill.)	40	7.33	No	0.538	2.076	0.500	3.114	0.016	1.958	1.047	0.093	3.114
2726		80	14.66	"	0.615	0.833	0.733	2.181	0.002	1.554	0.579	0.046	2.181
2727		80	14.66	"	1.995	3.922	1.027	6.944	0.007	4.846	2.023	0.068	6.944
2728		100	18.33	"	4.946	4.530	1.206	10.682	0.008	7.804	2.589	0.281	10.682
2729		120	22.00										
*2730		80	14.66	"	0.294	2.312	0.780	3.386	0.001	2.198	1.119	0.068	3.386
2738		40	7.33	Yes	1.394	1.213	0.199	2.806	0.023	1.856	0.861	0.066	2.806
2739		80	14.66	"	0.812	1.797	0.128	2.737	0.002	1.762	0.929	0.044	2.737
2740		80	14.66	"	0.604	1.119	0.191	1.914	0.003	1.137	0.744	0.030	1.914
2741		100	18.33	"	0.722	1.432	0.206	2.360	0.002	1.810	0.528	0.020	2.360
*2742		80	14.66	"	0.971	2.653	0.499	4.123	0.009	2.829	1.215	0.070	4.123
2743	Greene (Ind.)	40	7.33	"	0.193	1.529	0.504	2.226	0.014	1.312	0.844	0.056	2.226
2744		80	14.66	"	2.006	5.279	0.604	7.889	0.003	5.064	2.670	0.152	7.889
2745		80	14.66	"	2.116	3.817	0.510	6.443	0.019	4.214	2.086	0.124	6.443
2746		100	18.33	"	2.686	6.090	1.373	10.149	0.003	7.310	2.661	0.175	10.149
*2747		80	14.66	"	1.336	3.343	0.702	5.381	0.006	3.652	1.659	0.064	5.381
2780	Sullivan (Ind.)	40	7.33	"	0.803	1.868	0.447	3.118	0.041	1.930	1.051	0.096	3.118
2781		80	14.66	"	0.461	1.855	0.296	2.612	0.015	1.485	1.047	0.065	2.612
2782		80	14.66	"	0.927	2.571	0.716	4.214	0.024	2.852	1.234	0.104	4.214
2783		100	18.33	"	2.605	4.105	0.690	7.400	0.020	5.116	2.115	0.149	7.400
2784		120	22.00										
*2785		80	14.66	"	0.599	1.846	0.261	2.706	0.015	1.790	0.833	0.068	2.706
2786		40	7.33	No	0.665	2.389	0.319	3.373	0.031	1.995	1.266	0.091	3.373
2787		80	14.66	"	0.440	1.845	0.246	2.531	0.021	1.483	0.961	0.066	2.531
2788		80	14.66	"	1.228	3.281	0.396	4.905	0.031	2.995	1.758	0.121	4.905
2789		100	18.33	"	2.597	9.490	0.846	12.933	0.009	9.019	3.639	0.266	12.933
2760	Vermillion (Ind.)	40	7.33	Yes	1.261	4.217	1.460	6.938	0.103	3.901	2.674	0.260	6.938
2761		80	14.66	"	0.535	2.303	0.220	3.058	0.001	1.872	1.081	0.104	3.058
2762		80	14.66	"	1.133	3.041	0.575	4.749	0.024	3.247	1.355	0.123	4.749
2763		100	18.33	"	2.832	6.485	0.691	10.008	0.025	7.484	2.296	0.203	10.008
2764		120	22.00										
*2765		80	14.66	"	1.379	3.498	0.491	5.368	0.072	3.419	1.726	0.152	5.368
2766		40	7.33	No	0.287	1.280	0.164	1.731	0.002	1.029	0.670	0.030	1.731
2767		80	14.66	"	0.862	2.358	0.317	3.537	0.049	2.078	1.319	0.091	3.537
2768		80	14.66	"	2.000	4.601	0.493	7.094	0.042	4.862	2.005	0.185	7.094
2769		100	18.33	"	2.401	9.516	0.929	12.846	0.053	8.824	3.666	0.303	12.846
2754	Vigo (Ind.)	40	7.33	Yes	0.361	1.385	0.303	2.049	0.060	1.085	0.827	0.077	2.049
2755		80	14.66	"	0.951	2.882	0.372	4.205	0.012	2.438	1.637	0.118	4.205
2756		80	14.66	"	0.799	3.094	0.605	4.498	0.018	3.002	1.310	0.168	4.498
2757		100	18.33	"	1.166	4.085	0.823	6.074	0.012	4.575	1.308	0.179	6.074
2758		120	22.00										
*2759		80	14.66	"	1.356	3.337	0.966	5.659	0.017	3.810	1.643	0.189	5.659

* Fired by an inexperienced fireman.

TABLE CDLXXXVI. PHYSICAL AND CHEMICAL COMPOSITION OF GASES IN LOCOMOTIVE SMOKE AS DETERMINED BY ANALYSIS OF THE DISCHARGE FROM A LOCOMOTIVE SMOKE-STACK

(Tests made at Altoona, Pa.)

Test Number	County of Origin	R. P. M.	Miles per Hour	Brick Arch	Comparison of Fuel as Fired (By Weight) and Gases (By Weight—Pounds)					
					Per Cent of Fuel Fired					
					Carbon		Sulphur		Total	Total Gases
					As Carbon Dioxid	As Carbon Monoxid	Absorbed by Water	Absorbed by Iodine		
1	2	3	4	5	6	7	8	9	10	11
2715	Macoupin (Ill.)	40	7.33	No	57.625	0	.....	.....	.....	......
2716		80	14.66	"	57.938	0	.....	.....	.....	......
2717		80	14.66	"	48.779	7.173	.....	.....	.....	......
2718		100	18.33	"	48.092	6.156	.....	.....	.....	......
*2719		80	14.66	"	52.565	4.834	.....	.....	.....	......
2720		40	7.33	Yes	57.363	0	.....	.....	.....	......
2721		80	14.66	"	52.648	5.303	.....	.....	.....	......
2722		80	14.66	"	51.553	4.856	0.738	0.054	0.792	57.201
2723		100	18.33	"	44.831	8.508	0.165	0.318	0.483	53.822
2724		120	22.00							
2796	Marion (Ill.)	40	7.33	"	51.549	0	0.490	0.175	0.665	52.214
2797		80	14.66	"	51.665	0	0.482	0.305	0.787	52.452
2798		80	14.66	"	41.640	7.763	.....	.....	.....	......
2799		80	14.66	"	51.803	0	0.396	0.272	0.667	52.470
*2700		80	14.66	"	47.828	3.623	0.157	0.027	0.184	51.635
2790	Saline (Ill.)	40	7.33	"	67.963	1.096	0.025	0.003	0.028	69.087
2791		80	14.66	"	62.036	7.004	0.310	0.027	0.337	69.377
2792		80	14.66	"	64.058	2.683	0.729	0.352	1.081	67.722
2793		100	18.33	"	39.511	25.861	0.437	0.889	1.326	66.698
2794		120	22.00							
*2795		80	14.66	"	49.649	17.732	0.423	0.043	0.466	67.847
2732	Sangamon (Ill.)	40	7.33	"	57.147	0	2.371	0.207	2.578	59.725
2733		80	14.66	"	57.331	0	0.650	0.552	1.202	58.533
2734		80	14.66	"	56.595	0	0.808	1.392	2.200	58.795
2735		100	18.33	"	48.263	5.443	0.213	0.131	0.344	54.050
2736		120	22.00							
*2737		80	14.66	"	53.463	2.742	0.859	0.841	1.700	57.905
2748	Vermillion (Ill.)	40	7.33	"	53.040	1.768	.....	.....	.....	......
2749		80	14.66	"	54.966	0	0.446	0.045	0.491	55.457
2750		80	14.66	"	49.901	4.222	0.434	0.014	0.448	54.571
2751		100	18.33	"	40.778	8.783	0.240	0.190	0.430	49.991
2752		120	22.00							
*2753		80	14.66	"	54.536	0	0.251	0.235	0.486	55.022
2725	Williamson (Ill.)	40	7.33	No	(Air in	sample)	.....	.....	.....	......
2726		80	14.66	"	" "	"	.....	.....	.....	......
2727		80	14.66	"	55.488	2.988	0.034	0.003	0.037	58.513
2728		100	18.33	"	40.785	15.091	0.057	0.017	0.074	55.950
2729		120	22.00							
*2730		80	14.66	"	56.703	4.109	0.049	0.009	0.058	60.870
2738		40	7.33	Yes	63.344	0	0.206	0.027	0.233	63.577
2739		80	14.66	"	63.348	0	0.297	0.036	0.332	63.680
2740		80	14.66	"	52.324	11.708	0.026	0.007	0.033	64.065
2741		100	18.33	"	51.187	12.133	.....	.....	.....	......
*2742		80	14.66	"	62.441	0	0.021	0.002	0.023	62.464
2743	Greene (Ind.)	40	7.33	"	56.338	0	1.356	0.199	1.555	57.693
2744		80	14.66	"	53.976	0	0.390	0.254	0.644	54.620
2745		80	14.66	"	48.393	5.943	0.383	0.204	0.587	54.923
2746		100	18.33	"	51.650	0	0.596	1.395	1.991	63.641
*2747		80	14.66	"	(Air in	sample)	.....	.....	.....	......
2780	Sullivan (Ind.)	40	7.33	"	" "	"	.....	.....	.....	......
2781		80	14.66	"	51.542	5.053	1.144	0.312	1.456	58.051
2782		80	14.66	"	55.268	0	0.822	0.461	1.283	56.541
2783		100	18.33	"	43.772	8.622	0.799	1.002	1.801	54.195
2784		120	22.00							
*2785		80	14.66	"	55.204	0.936	0.722	0.208	0.930	57.070
2786		40	7.33	No	55.308	1.257	1.057	0.382	1.439	58.004
2787		80	14.66	"	56.957	0	0.455	0.104	0.559	57.516
2788		80	14.66	"	51.991	3.773	0.272	0.028	0.300	56.064
2789		100	18.33	"	43.517	6.994	0.369	0.182	0.551	51.062
2760	Vermillion (Ind.)	40	7.33	Yes	52.789	0	1.238	0.791	2.029	54.818
2761		80	14.66	"	53.708	0	2.295	1.359	3.654	57.362
2762		80	14.66	"	52.453	0	1.006	0.535	1.541	53.994
2763		100	18.33	"	43.754	4.862	0.852	0.736	1.588	50.204
2764		120	22.00							
*2765		80	14.66	"	51.567	0.874	1.179	0.599	1.778	54.219
2766		40	7.33	No	52.981	0	1.866	0.892	2.758	55.739
2767		80	14.66	"	52.282	0	1.388	0.768	2.156	54.438
2768		80	14.66	"	36.981	12.887	0.212	0.228	0.440	50.308
2769		100	18.33	"	40.350	6.456	0.824	0.180	1.004	47.810
2754	Vigo (Ind.)	40	7.33	Yes	56.505	0	0.825	1.325	2.150	58.655
2755		80	14.66	"	55.342	0	0.522	0.158	0.680	56.022
2756		80	14.66	"	54.722	0	0.884	1.725	2.609	57.331
2757		100	18.33	"	48.757	4.388	1.275	2.451	3.726	56.871
2758		120	22.00							
*2759		80	14.66		54.000	0	1.990	2.410	4.400	58.400

Fired by an inexperienced fireman.

TABLE CDLXXXVII. SOLID CONSTITUENTS OF LOCOMOTIVE SMOKE AS DETERMINED BY ANALYSIS OF THE DISCHARGE FROM A LOCOMOTIVE SMOKE-STACK

(Tests made at Altoona, Pa.)

Test Number	County of Origin	R. P. M.	Miles per Hour	Brick Arch	Composition of Discharge								
					Per Cent of Solid Constituents of Smoke (By Weight)								
					Physical Classification				Chemical Classification				
					Coarse Cinders	Fine Cinders	Fuel Dust	Total Cinders and Dust	Hydro-Carbons (Tar)	Combustible Solids (Carbon)	Mineral Matter (Ash)	Sulphur	Total
1	2	3	4	5	6	7	8	9	10	11	12	13	14
2715	Macoupin (Ill.)	40	7.33	No	12.55	73.60	13.85	100	0.24	66.15	31.07	2.54	100
2716		80	14.66	"	29.23	60.00	10.77	100	0.09	53.93	43.68	2.30	100
2717		80	14.66	"	35.29	57.84	6.87	100	0.15	73.22	23.92	2.71	100
2718		100	18.33	"	38.97	56.18	4.85	100	0.17	77.06	20.03	2.74	100
*2719		80	14.66	"	25.87	67.95	6.18	100	0.42	68.50	28.32	2.76	100
2720		40	7.33	Yes	18.93	74.64	6.43	100	1.54	69.85	25.23	3.38	100
2721		80	14.66	"	20.91	66.82	12.27	100	0.26	58.15	38.80	2.79	100
2722		80	14.66	"	40.70	52.56	6.74	100	0.26	70.38	28.31	1.05	100
2723		100	18.33	"	36.36	53.12	10.52	100	0.14	79.49	17.42	2.95	100
2724		120	22.00										
2796	Marion (Ill.)	40	7.33	"	18.73	62.54	18.73	100	0.26	60.79	36.03	2.92	100
2797		80	14.66	"	34.00	56.50	9.50	100	0.36	54.02	43.36	2.26	100
2798		80	14.66	"	41.77	42.00	16.23	100	0.26	69.36	26.62	3.76	100
2799		80	14.66	"	20.83	71.95	7.22	100	0.37	57.58	37.99	4.06	100
*2700		80	14.66	"	37.78	40.37	21.85	100	0.46	65.26	32.17	2.11	100
2790	Saline (Ill.)	40	7.33	"	16.40	69.20	14.40	100	0.57	64.80	32.24	2.39	100
2791		80	14.66	"	19.05	66.67	14.28	100	0.49	66.84	31.22	1.45	100
2792		80	14.66	"	21.74	67.39	10.87	100	0.25	73.76	21.57	1.42	100
2793		100	18.33	"	29.71	59.42	10.87	100	0.33	77.33	20.68	1.60	100
2794		120	22.00										
*2795		80	14.66	"	31.34	57.12	11.54	100	0.23	74.77	23.35	1.65	100
2732	Sangamon (Ill.)	40	7.33	"	14.41	65.59	20.00	100	0.67	46.66	49.98	2.69	100
2733		80	14.66	"	23.22	63.03	13.75	100	0.58	54.61	41.87	2.94	100
2734		80	14.66	"	14.32	71.36	14.32	100	0.55	59.88	36.55	3.02	100
2735		100	18.33	"	47.38	46.15	6.47	100	0.15	76.09	23.00	0.76	100
2736		120	22.00										
*2737		80	14.66	"	13.68	75.53	10.79	100	0.43	61.59	34.40	3.58	100
2748	Vermillion (Ill.)	40	7.33	"	14.81	64.08	21.11	100	1.17	67.85	26.03	4.95	100
2749		80	14.66	"	21.38	65.52	13.10	100	0.17	60.83	37.15	1.85	100
2750		80	14.66	"	47.62	45.00	7.38	100	0.29	60.86	36.78	2.07	100
2751		100	18.33	"	31.33	60.11	8.56	100	0.03	79.15	19.28	1.54	100
2752		120	22.00										
*2753		80	14.66	"	24.45	65.07	10.48	100	0.02	69.63	28.72	1.63	100
2725	Williamson (Ill.)	40	7.33	No	17.27	66.67	16.06	100	0.51	62.88	33.63	2.98	100
2726		80	14.66	"	28.18	38.18	33.64	100	0.09	71.24	26.55	2.12	100
2727		80	14.66	"	28.73	56.48	14.79	100	0.11	69.79	29.13	0.97	100
2728		100	18.33	"	46.30	42.41	11.29	100	0.08	73.05	24.24	2.63	100
2729		120	22.00										
*2730		80	14.66	"	8.67	68.29	23.04	100	0.01	64.92	33.06	2.01	100
2738		40	7.33	Yes	49.68	43.23	7.09	100	0.82	66.13	30.70	2.35	100
2739		80	14.66	"	29.67	65.67	4.66	100	0.08	64.34	33.96	1.62	100
2740		80	14.66	"	31.54	58.46	10.00	100	0.15	59.38	38.92	1.55	100
2741		100	18.33	"	30.59	60.67	8.74	100	0.07	76.72	22.36	0.85	100
*2742		80	14.66	"	23.54	64.34	12.12	100	0.23	68.60	29.48	1.69	100
2743	Greene (Ind.)	40	7.33	"	8.69	68.70	22.61	100	0.63	58.92	37.90	2.55	100
2744		80	14.66	"	25.43	66.92	7.65	100	0.04	64.19	33.84	1.93	100
2745		80	14.66	"	32.84	59.25	7.91	100	0.29	65.41	32.38	1.92	100
2746		100	18.33	"	26.47	60.00	13.53	100	0.03	72.03	26.22	1.72	100
*2747		80	14.66	"	24.82	62.14	13.04	100	0.12	67.87	30.83	1.18	100
2780	Sullivan (Ind.)	40	7.33	"	25.74	59.91	14.35	100	1.31	61.90	33.71	3.08	100
2781		80	14.66	"	17.67	71.00	11.33	100	0.57	56.85	40.10	2.48	100
2782		80	14.66	"	22.00	61.00	17.00	100	0.59	67.87	29.28	2.26	100
2783		100	18.33	"	35.20	55.47	9.33	100	0.27	69.13	28.58	2.02	100
2784		120	22.00										
*2785		80	14.66	"	22.14	68.22	9.64	100	0.54	66.15	30.80	2.51	100
2786		40	7.33	No	19.73	70.81	9.46	100	0.91	59.16	37.23	2.70	100
2787		80	14.66	"	17.39	72.91	9.70	100	0.82	58.60	37.96	2.62	100
2788		80	14.66	"	25.04	66.90	8.06	100	0.63	61.06	35.85	2.46	100
2789		100	18.33	"	20.08	73.38	6.54	100	0.07	69.74	28.14	2.05	100
2760	Vermillion (Ind.)	40	7.33	Yes	18.18	60.78	21.04	100	1.49	56.23	38.54	3.74	100
2761		80	14.66	"	17.50	75.31	7.19	100	0.04	61.23	35.35	3.38	100
2762		80	14.66	"	23.85	64.04	12.11	100	0.51	68.38	28.53	2.58	100
2763		100	18.33	"	28.30	64.80	6.80	100	0.25	74.78	22.94	2.03	100
2764		120	22.00										
*2765		80	14.66	"	25.69	65.17	9.14	100	1.34	63.69	32.13	2.84	100
2766		40	7.33	No	16.57	73.96	9.47	100	0.14	59.44	38.69	1.73	100
2767		80	14.66	"	21.36	66.67	8.97	100	1.37	58.75	37.30	2.58	100
2768		80	14.66	"	28.19	64.86	6.95	100	0.54	68.58	28.26	2.62	100
2769		100	18.33	"	18.69	74.08	7.23	100	0.41	68.69	28.54	2.36	100
2754	Vigo (Ind.)	40	7.33	Yes	17.60	67.60	14.80	100	2.96	52.93	40.35	3.76	100
2755		80	14.66	"	22.61	68.53	8.86	100	0.28	57.98	38.92	2.82	100
2756		80	14.66	"	17.76	68.79	13.45	100	0.40	66.75	29.13	3.72	100
2757		100	18.33	"	19.19	67.26	13.55	100	0.19	75.33	21.54	2.94	100
2758		120	22.00										
*2759		80	14.66	"	23.96	58.97	17.07	100	0.30	67.33	29.03	3.34	100

* Fired by an inexperienced fireman.

TABLE CDLXXXVIII. GASEOUS CONSTITUENTS OF LOCOMOTIVE SMOKE AS DETERMINED BY ANALYSIS OF THE DISCHARGE FROM A LOCOMOTIVE SMOKE-STACK

(Tests made at Altoona, Pa.)

Test Number	County of Origio	R.P.M.	Miles per Hour	Brick Arch	Composition of Discharge							
					Per Cent of Gases (By Volume)							
					(CO_2) Carbon Dioxid	(CO) Carbon Monoxid	(O) Oxygen	(N) Nitrogen	Sulphur (S)			Total Gases
									Absorbed by Water	Absorbed by Iodine	Total	
1	2	3	4	5	6	7	8	9	10	11	12	13
2715	Maeoupin (Ill.)	40	7.33	No	12.2	0	7.2	....	......	......	......	...
2716		80	14.66	"	12.6	0	5.9	....	......	......	......	...
2717		80	14.66	"	13.6	2.0	3.2	....	......	......	......	...
2718		100	18.33	"	12.5	1.6	3.7	....	......	......	......	...
*2719		80	14.66	"	8.7	0.8	11.3	....	......	......	......	...
2720		40	7.33	Yes	13.8	0	3.6	....	......	......	......	...
2721		80	14.66	"	13.9	1.4	3.9	....	......	......	......	...
2722		80	14.66	"	13.8	1.3	2.2	82.6204	0.0742	0.0054	0.0796	100
2723		100	18.33	"	14.2	2.1	1.1	81.5445	0.0190	0.0365	0.0555	100
2724		120	22.00		13.7	2.6	2.1					
2796	Marioo (Ill.)	40	7.33	"	13.0	0	3.8	83.1371	0.0463	0.0166	0.0629	100
2797		80	14.66	"	11.8	0	5.8	82.3325	0.0414	0.0261	0.0675	100
2798		80	14.66	"	11.8	2.2	7.8	....	......	......	......	...
2799		80	14.66	"	12.2	0	6.0	81.7411	0.0349	0.0240	0.0589	100
*2700		80	14.66	"	13.2	1.0	2.6	83.1809	0.0163	0.0028	0.0191	100
2790	Saline (Ill.)	40	7.33	"	12.4	0.2	5.2	82.1980	0.0017	0.0003	0.0020	100
2791		80	14.66	"	12.4	1.4	3.8	82.3748	0.0232	0.0020	0.0252	100
2792		80	14.66	"	12.4	0.6	3.8	83.1214	0.0530	0.0256	0.0786	100
2793		100	18.33	"	12.8	4.0	2.0	81.4617	0.0455	0.0928	0.1383	100
2794		120	22.00		11.0	7.2	0.2					
*2795		80	14.66	"	11.2	4.0	2.8	81.9607	0.0358	0.0035	0.0393	100
2732	Sangamon (Ill.)	40	7.33	"	10.6	0	8.4	80.8207	0.1649	0.0144	0.1793	100
2733		80	14.66	"	11.3	0	7.3	81.3113	0.0480	0.0407	0.0887	100
2734		80	14.66	"	13.4	0	4.8	81.6028	0.0717	0.1255	0.1972	100
2735		100	18.33	"	11.7	0.4	5.8	81.9445	0.0220	0.1335	0.1555	100
2736		120	22.00		13.3	1.5	3.0					
*2737		80	14.66	"	15.6	0.8	1.6	81.8140	0.0940	0.0920	0.1860	100
2748	Vermillion (Ill.)	40	7.33	"	12.0	0.4	4.2	....	......	......	......	...
2749		80	14.66	"	11.5	0	7.0	81.4305	0.0350	0.0345	0.0695	100
2750		80	14.66	"	13.0	1.1	3.9	81.9553	0.0434	0.0013	0.0447	100
2751		100	18.33	"	12.8	3.7	2.7	80.7487	0.0286	0.0227	0.0513	100
2752		120	22.00		13.0	2.8	1.0					
*2753		80	14.66	"	7.0	0	11.6	81.3766	0.0121	0.0113	0.0234	100
2725	Williamson (Ill.)	40	7.33	No	Air io	sample	...	....	0.0413	0.0003	0.0416	...
2726		80	14.66	"	" "	"	...	....	0.0091	0.0013	0.0104	...
2727		80	14.66	"	13.0	0.7	4.7	81.5948	0.0030	0.0022	0.0052	100
2728		100	18.33	"	14.7	1.3	2.5	81.0932	0.0052	0.0016	0.0068	100
2729		120	22.00		10.0	3.7	5.2					
*2730		80	14.66	"	13.8	1.0	3.6	81.5947	0.0045	0.0008	0.0053	100
2738		40	7.33	Yes	16.4	0	1.9	81.6776	0.0200	0.0024	0.0224	100
2739		80	14.66	"	13.1	0	5.4	81.4744	0.0230	0.0026	0.0256	100
2740		80	14.66	"	14.3	3.2	0.9	81.5966	0.0027	0.0007	0.0034	100
2741		100	18.33	"	13.5	3.2	1.5	....	......	......	......	...
*2742		80	14.66	"	10.5	0	8.5	80.9856	0.0130	0.0014	0.0144	100
2743	Greeoe (Ind.)	40	7.33	"	6.1	0	13.4	80.4368	0.0551	0.0081	0.0632	100
2744		80	14.66	"	15.4	0	3.6	80.9311	0.0417	0.0272	0.0689	100
2745		80	14.66	"	11.4	1.4	6.6	80.5483	0.0339	0.0178	0.0517	100
2746		100	18.33	"	11.4	0	6.8	81.6351	0.0494	0.1155	0.1649	100
*2747		80	14.66	"	Air in	sample	...	....	0.0385	0.0283	0.0668	...
2780	Sullivan (Ind.)	40	7.33	"	" "	"	...	....	0.0631	0.0201	0.0832	...
2781		80	14.66	"	10.2	1.0	6.8	81.8921	0.0848	0.0231	0.1079	100
2782		80	14.66	"	12.4	0	5.8	81.6920	0.0692	0.0388	0.1080	100
2783		100	18.33	"	13.2	0.4	4.2	81.9966	0.0902	0.1132	0.2034	100
2784		120	22.00		13.2	2.6	2.2					
*2785		80	14.66	"	11.8	0.2	5.4	82.5256	0.0578	0.0166	0.0744	100
2786		40	7.33	No	8.8	0.2	9.2	81.7141	0.0631	0.0228	0.0859	100
2787		80	14.66	"	12.6	0	6.0	81.3536	0.0377	0.0087	0.0464	100
2788		80	14.66	"	12.4	0.9	4.4	82.2516	0.0242	0.0242	0.0484	100
2789		100	18.33	"	11.2	1.8	5.0	81.9468	0.0357	0.0175	0.0532	100
2760	Vermillioo (Ind.)	40	7.33	Yes	14.4	0	3.2	82.1924	0.1266	0.0810	0.2076	100
2761		80	14.66	"	8.4	0	10.6	80.7947	0.1256	0.0797	0.2053	100
2762		80	14.66	"	11.4	0	6.6	81.8742	0.0821	0.0437	0.1258	100
2763		100	18.33	"	12.0	0.2	4.8	82.8284	0.0922	0.0794	0.1716	100
2764		120	22.00		12.6	1.4	4.0					
*2765		80	14.66	"	11.8	0.2	5.7	82.1474	0.1012	0.0514	0.1526	100
2766		40	7.33	No	9.0	0	9.2	81.6213	0.1189	0.0568	0.1757	100
2767		80	14.66	"	10.2	0	8.0	81.6423	0.1015	0.0562	0.1577	100
2768		80	14.66	"	13.2	4.6	4.4	77.7411	0.0284	0.0305	0.0589	100
2769		100	18.33	"	10.0	1.6	3.8	84.5068	0.0765	0.0167	0.0932	100
2754	Vigo (Ind.)	40	7.33	Yes	12.4	0	5.6	81.8235	0.0679	0.1086	0.1765	100
2755		80	14.66	"	8.6	0	10.0	81.3604	0.0304	0.0092	0.0396	100
2756		80	14.66	"	11.2	0	6.8	81.7997	0.0679	0.1324	0.2003	100
2757		100	18.33	"	10.4	0.4	6.6	82.3133	0.0982	0.1885	0.2867	100
2758		120	22.00		10.0	0.9	6.0					
*2759		80	14.66	"	6.5	0	12.5	80.8015	0.0899	0.1086	0.1985	100

* Fired by an inexperienced fireman.

TABLE CDLXXXIX. SULPHUR IN GASES OF LOCOMOTIVE SMOKE AS DETERMINED BY ANALYSIS OF THE DISCHARGE FROM A LOCOMOTIVE SMOKE-STACK
(Tests made at Altoona, Pa.)

Test Number	County of Origin	R. P. M.	Miles per Hour	Brick Arch	Sulphur (By Weight)							
					Per Cent in Coal Fired	Pounds Fired During Test	Gaseous					
							In Per Cent of Coal Fired			In Per Cent of Sulphur Fired		
							Absorbed by Water	Absorbed by Iodine	Total	Absorbed by Water	Absorbed by Iodine	Total
1	2	3	4	5	6	7	8	9	10	11	12	13
2715	Macoupin (Ill.)	40	7.33	No	4.05	125.8	.....	.....	.....	.....	.....	.....
2716		80	14.66	"	4.05	284.9	.....	.....	.....	.....	.....	.....
2717		80	14.66	"	4.05	406.7	.....	.....	.....	.....	.....	.....
2718		100	18.33	"	4.05	293.6	.....	.....	.....	.....	.....	.....
*2719		80	14.66	"	4.05	345.6	.....	.....	.....	.....	.....	.....
2720		40	7.33	Yes	4.05	166.7	.....	.....	.....	.....	.....	.....
2721		80	14.66	"	4.05	267.9	.....	.....	.....	.....	.....	.....
2722		80	14.66	"	4.05	389.6	0.738	0.054	0.792	18.22	1.33	19.55
2723		100	18.33	"	4.05	444.9	0.165	0.318	0.483	4.07	7.85	11.92
2724		120	22.00	"	4.05							
2796	Marion (Ill.)	40	7.33	"	2.82	126.9	0.490	0.175	0.665	17.38	6.20	23.58
2707		80	14.66	"	2.82	178.5	0.482	0.305	0.787	17.09	10.82	27.91
2798		80	14.66	"	2.82	297.9	.....	.....	.....	.....	.....	.....
2799		80	14.66	"	2.82	180.1	0.395	0.272	0.667	14.01	9.64	23.65
*2700		80	14.66	"	2.82	227.7	0.157	0.027	0.184	5.56	0.96	6.52
2790	Saline (Ill.)	40	7.33	"	2.33	76.3	0.025	0.003	0.028	1.07	0.13	1.20
2791		80	14.66	"	2.33	120.4	0.310	0.027	0.337	13.30	1.16	14.46
2792		80	14.66	"	2.33	176.3	0.720	0.352	1.081	31.29	15.11	46.40
2793		100	18.33	"	2.33	217.7	0.437	0.889	1.326	18.76	38.15	56.91
2794		120	22.00	"	2.33							
*2795		80	14.66	"	2.33	177.9	0.423	0.043	0.466	18.15	1.85	20.00
2732	Sangamon (Ill.)	40	7.33	"	3.56	125.2	2.371	0.207	2.578	66.60	5.82	72.42
2733		80	14.66	"	3.56	243.3	0.650	0.552	1.202	18.26	15.50	33.76
2734		80	14.66	"	3.56	336.2	0.808	1.392	2.200	22.70	39.10	61.80
2735		100	18.33	"	3.56	428.2	0.213	0.131	0.344	5.98	3.68	9.66
2736		120	22.00	"	3.56							
*2737		80	14.66	"	3.56	114.7	0.859	0.841	1.700	24.13	23.62	47.75
2748	Vermillion (Ill.)	40	7.33	"	2.69	92.2	.....	.....	.....	.....	.....	.....
2749		80	14.66	"	2.69	166.8	0.446	0.045	0.491	16.58	1.67	18.25
2750		80	14.66	"	2.69	230.4	0.434	0.014	0.448	16.13	0.52	16.65
2751		100	18.33	"	2.69	351.0	0.240	0.190	0.430	8.92	7.06	15.98
2752		120	22.00	"	2.69							
*2753		80	14.66	"	2.69	208.6	0.251	0.235	0.486	9.33	8.74	18.07
2725	Williamson (Ill.)	40	7.33	No	0.70	24.8	.....	.....	.....	.....	.....	.....
2726		80	14.66	"	0.70	43.6	.....	.....	.....	.....	.....	.....
2727		80	14.66	"	0.70	68.1	0.034	0.003	0.037	4.86	0.43	5.29
2728		100	18.33	"	0.70	68.8	0.057	0.017	0.074	8.14	2.43	10.57
2729		120	22.00	"	0.70							
*2730		80	14.66	"	0.70	42.8	0.049	0.009	0.058	7.00	1.29	8.29
2738		40	7.33	Yes	0.70	22.3	0.206	0.027	0.233	29.43	3.86	33.29
2739		80	14.66	"	0.70	41.8	0.297	0.035	0.332	42.43	5.00	47.43
2740		80	14.66	"	0.70	62.1	0.026	0.007	0.033	3.71	1.00	4.71
2741		100	18.33	"	0.70	49.0	.....	.....	.....	.....	.....	.....
*2742		80	14.66	"	0.70	46.3	0.021	0.002	0.023	3.00	0.29	3.29
2743	Greene (Ind.)	40	7.33	"	2.72	87.3	1.356	0.199	1.555	49.85	7.32	57.17
2744		80	14.66	"	2.72	151.6	0.390	0.254	0.644	14.34	9.34	23.68
2745		80	14.66	"	2.72	216.2	0.383	0.204	0.587	14.08	7.50	21.58
2746		100	18.33	"	2.72	225.5	0.596	1.395	1.991	21.91	51.29	73.20
*2747		80	14.66	"	2.72	186.8	.....	.....	.....	.....	.....	.....
2780	Sullivan (Ind.)	40	7.33	"	3.25	133.8	.....	.....	.....	.....	.....	.....
2781		80	14.66	"	3.25	195.6	1.144	0.312	1.456	35.20	9.60	44.80
2782		80	14.66	"	3.25	276.0	0.822	0.461	1.283	25.29	14.18	39.47
2783		100	18.33	"	3.25	403.6	0.799	1.002	1.801	24.58	30.83	55.41
2784		120	22.00	"	3.25							
*2785		80	14.66	"	3.25	274.8	0.722	0.208	0.930	22.22	6.40	28.62
2786		40	7.33	No	3.25	133.4	1.057	0.382	1.439	32.52	11.75	44.27
2787		80	14.66	"	3.25	190.2	0.455	0.104	0.559	14.00	3.20	17.20
2788		80	14.66	"	3.25	324.0	0.272	0.028	0.300	8.37	0.86	9.23
2789		100	18.33	"	3.25	204.2	0.369	0.182	0.551	11.35	5.60	16.95
2760	Vermillion (Ind.)	40	7.33	Yes	4.28	153.4	1.238	0.791	2.029	28.93	18.48	47.41
2761		80	14.66	"	4.28	240.5	2.295	1.359	3.654	53.62	31.75	85.37
2762		80	14.66	"	4.28	368.6	1.006	0.535	1.541	23.50	12.50	36.00
2763		100	18.33	"	4.28	431.7	0.852	0.736	1.588	19.91	17.19	37.10
2764		120	22.00	"	4.28							
*2765		80	14.66	"	4.28	311.9	1.179	0.599	1.778	27.54	14.00	41.54
2766		40	7.33	No	4.28	169.7	1.866	0.892	2.758	43.60	20.84	64.44
2767		80	14.66	"	4.28	282.4	1.388	0.768	2.156	32.43	17.94	50.37
2768		80	14.66	"	4.28	421.1	0.212	0.228	0.440	4.95	5.33	10.28
2769		100	18.33	"	4.28	286.9	0.824	0.180	1.004	19.25	4.21	23.46
2754	Vigo (Ind.)	40	7.33	Yes	4.75	162.5	0.825	1.325	2.150	17.37	27.89	45.26
2755		80	14.66	"	4.75	275.9	0.522	0.158	0.680	10.99	3.33	14.32
2756		80	14.66	"	4.75	433.8	0.884	1.725	2.609	18.61	36.32	54.93
2757		100	18.33	"	4.75	560.1	1.275	2.451	3.726	26.84	51.60	78.44
2758		120	22.00	"	4.75							
*2759		80	14.66	"	4.75	303.9	1.990	2.410	4.400	41.89	50.74	92.63

* Fired by an inexperienced fireman.

TABLE CDXC. EQUIVALENT EVAPORATION PER POUND OF DRY COAL WHEN PRODUCING AN EQUIVALENT EVAPORATION RANGING FROM FOUR TO TWELVE POUNDS OF WATER PER SQUARE FOOT OF HEATING SURFACE PER HOUR

(Tests made at Altoona, Pa.)

County of Origin	Equivalent Evaporation per Square Foot of Heating Surface per Hour										Rating Per Cent*
	Pounds of Water										
	4	5	6	7	8	9	10	11	12	Avg.	
1	2	3	4	5	6	7	8	9	10	11	12
Group BA-10. With Brick Arch											
Macoupin (Ill.)	9.7	9.5	9.3	9.1	8.8	8.5	8.2	7.8	7.6	8.7	93.5
Marion (Ill.)	8.7	8.7	8.7	8.6	8.3	8.1	7.8	7.4	7.0	8.2	88.1
Saline (Ill.)	10.7	10.7	10.7	10.5	10.2	9.8	9.3	8.7	7.9	9.8	105.3
Sangamon (Ill.)	9.3	9.4	9.4	9.4	9.3	9.2	9.0	8.7	8.2	9.1	97.8
Vermillion (Ill.)	10.7	10.6	10.3	9.9	9.6	9.2	8.8	8.3	7.8	9.5	102.1
Williamson (Ill.)	10.3	10.3	10.2	10.1	10.0	9.7	9.3	8.7	7.7	9.6	103.2
Greene (Ind.)	10.7	10.7	10.7	10.6	10.5	10.3	10.0	9.6	8.8	10.2	109.6
Sullivan (Ind.)	9.9	10.0	10.0	9.8	9.6	9.3	8.8	8.3	7.8	9.3	100.0
Vermillion (Ind.)	9.7	9.7	9.6	9.5	9.3	9.0	8.7	8.2	7.8	9.1	97.8
Vigo (Ind.)	9.9	9.9	9.7	9.5	9.3	8.9	8.5	8.0	7.5	9.0	96.8
Averages	10.0	10.0	9.9	9.7	9.5	9.2	8.8	8.4	7.8	9.3	100.0
Group NA-4. Without Brick Arch											
Macoupin (Ill.)	9.7	9.1	8.5	8.2	7.8	7.7	7.7	7.8	8.3	8.3	96.5
Williamson (Ill.)	10.2	9.8	9.4	9.0	8.7	8.3	8.1	7.8	7.6	8.8	102.3
Sullivan (Ind.)	9.3	9.4	9.4	9.3	9.0	8.7	8.2	7.7	7.0	8.7	101.1
Vermillion (Ind.)	9.6	9.6	9.4	9.2	8.8	8.3	7.7	6.9	6.0	8.4	97.7
Averages	9.7	9.5	9.2	8.9	8.6	8.3	7.9	7.6	7.2	8.6	100.0
Group BA-4. With Brick Arch											
Macoupin (Ill.)	9.7	9.5	9.3	9.1	8.8	8.5	8.2	7.8	7.6	8.7	94.6
Williamson (Ill.)	10.3	10.3	10.2	10.1	10.0	9.7	9.3	8.7	7.7	9.6	104.3
Sullivan (Ind.)	9.9	10.0	10.0	9.8	9.6	9.3	8.8	8.3	7.8	9.3	101.1
Vermillion (Ind.)	9.7	9.7	9.6	9.5	9.3	9.0	8.7	8.2	7.8	9.1	98.9
Averages	9.9	9.9	9.8	9.6	9.4	9.1	8.8	8.3	7.7	9.2	100.0

* "Rating Per Cent" is on the basis of the average for the group.

from 4 to 12 pounds of water evaporated per square foot of heating surface per hour. The values themselves, in terms of equivalent evaporation per pound of fuel, vary from 6.0 to 10.7 pounds of water.

In the variation from 4 to 12 pounds, an increase of 200 per cent in the water evaporated per square foot of heating surface per hour and consequently in the boiler horse-power, there was a decrease in the average equivalent evaporation per pound of dry coal from 10.0 to 7.8 pounds for group BA-10, from 9.7 to 7.2 pounds for group NA-4 and from 9.9 to 7.7 pounds for group BA-4.

The average equivalent evaporation per pound of dry coal was 8.6 pounds for group NA-4 and 9.2 pounds for group BA-4, an increase of 0.6 pounds, or about 7 per cent in favor of the use of the brick arch when burning coals of the same kind.

701.49 Boiler Efficiency: Determination was made of boiler efficiency as developed with each of the ten coals tested at rates of combustion varying from 30 to 100 pounds of coal per square foot of grate surface per hour, the increase in rate proceeding by increments of 10. Values for boiler efficiency in per cent are set forth for the several rates of combustion in table CDXCI.

In order to rate the several coals tested on the basis of boiler efficiency, the average values given in column 10 of table CDXCI were averaged and the result thus obtained was taken as 100. The highest value obtained for any coal was 5.9 per cent above, and the lowest was 7.7 per cent below, the general average.

As the rates of combustion increased from 30 to 100 pounds of coal per square foot of grate surface per hour, there was a decrease in the average boiler efficiency from 75.1 per cent to 58.0 per cent for group BA-10, from 72.6 per cent to 55.2 per cent for group NA-4 and from 75.1 per cent to 58.2 per cent for group BA-4. The presence of the brick arch in the locomotive fire-box was, therefore, responsible for an increase of 4.4 per cent in boiler efficiency.

701.50 Dynamometer Horse-Power: Each of the ten coals tested was rated on the basis of the quantity of fuel consumed per dynamometer horse-power-hour, determinations having been made to cover the periods of the tests during which the locomotive was developing from 300 to 1,000 dynamometer horse-power. To obtain comparable values for the various samples of coal, the values presented in table CDLXXXIV were plotted and a smooth curve was drawn through the points thus located. Values were taken from this curve for each predetermined rate of power developed at the draw bar, these rates varying, as stated, from 300 to 1,000 dynamometer horse-power, the increase proceeding by increments of 100. Values thus obtained, expressed in pounds of coal consumed per dynamometer horse-power-hour, are shown by table CDXCII.

To provide a basis upon which comparisons might be drawn, the average values presented in column 10 of table CDXCII were averaged and the result thus obtained was taken as 100. Ratings of the several coals, expressed in per cent of this average, are given in the last column of the table. From the ratings thus established, it appears that for six of the coals the average quantity consumed per dynamometer horse-power-hour was less than the general average, for two of the coals it was the same as the general average and for two others it was more than the general

TABLE CDXCI. BOILER EFFICIENCY UNDER RATES OF FIRING VARYING FROM 30 TO 100 POUNDS OF COAL PER SQUARE FOOT OF GRATE SURFACE PER HOUR

(Tests made at Altoona, Pa.)

County of Origin	Pounds of Coal Fired per Square Foot of Grate Surface per Hour									Rating Per Cent*
	30 Per Cent	40 Per Cent	50 Per Cent	60 Per Cent	70 Per Cent	80 Per Cent	90 Per Cent	100 Per Cent	Average Per Cent	
1	2	3	4	5	6	7	8	9	10	11
Group BA-10. With Brick Arch										
Macoupin (Ill.)	73.6	71.7	69.4	67.0	64.8	62.5	60.3	58.0	65.9	97.3
Marion (Ill.)	68.7	68.0	66.5	64.5	62.1	59.6	56.7	53.8	62.5	92.3
Saline (Ill.)	74.5	72.5	70.2	67.5	64.7	61.6	58.5	55.2	65.6	96.9
Sangamon (Ill.)	72.0	72.0	71.8	71.0	69.4	66.9	63.7	60.0	68.4	101.0
Vermillion (Ill.)	81.0	78.2	75.5	72.7	70.2	67.7	65.2	62.6	71.6	105.8
Williamson (Ill.)	78.4	77.5	75.6	73.0	69.7	66.0	61.8	57.8	70.0	103.4
Greene (Ind.)	79.5	78.7	77.5	75.3	72.0	68.2	63.7	58.8	71.7	105.9
Sullivan (Ind.)	71.8	71.3	70.4	69.2	67.3	65.0	62.2	59.0	67.0	99.0
Vermillion (Ind.)	76.5	75.2	73.1	70.6	67.7	64.6	61.2	57.8	68.3	100.9
Vigo (Ind.)	74.6	72.2	69.7	67.2	64.7	62.2	59.7	57.3	66.0	97.5
Averages	75.1	73.7	72.0	69.8	67.3	64.4	61.3	58.0	67.7	100.0
Group NA-4. Without Brick Arch										
Macoupin (Ill.)	71.4	66.7	63.0	60.2	58.8	59.0	60.8	63.5	62.9	99.2
Williamson (Ill.)	75.5	72.0	68.8	65.5	62.0	58.7	55.3	52.2	63.8	100.6
Sullivan (Ind.)	70.3	69.1	67.2	64.8	62.0	59.1	56.0	53.0	62.7	98.9
Vermillion (Ind.)	73.0	72.0	70.0	67.3	63.9	60.1	56.2	52.0	64.3	101.4
Averages	72.6	69.9	67.3	64.5	61.7	59.2	57.1	55.2	63.4	100.0
Group BA-4. With Brick Arch										
Macoupin (Ill.)	73.6	71.7	69.4	67.0	64.8	62.5	60.3	58.0	65.9	97.2
Williamson (Ill.)	78.4	77.5	75.6	73.0	69.7	66.0	61.8	57.8	70.0	103.3
Sullivan (Ind.)	71.8	71.3	70.4	69.2	67.3	65.0	62.2	59.0	67.0	98.8
Vermillion (Ind.)	76.5	75.2	73.1	70.6	67.7	64.6	61.2	57.8	68.3	100.7
Averages	75.1	73.9	72.1	69.9	67.4	64.5	61.4	58.2	67.8	100.0

* "Rating Per Cent" is on the basis of the average for the group.

TABLE CDXCII. QUANTITY OF DRY COAL CONSUMED BY TEST LOCOMOTIVE PER DYNAMOMETER HORSE-POWER-HOUR WHEN DEVELOPING FROM 300 TO 1,000 DYNAMOMETER HORSE-POWER

(Tests made at Altoona, Pa.)

County of Origin	Dynamometer Horse-Power									Rating Per Cent*
	300 Pounds of Coal	400 Pounds of Coal	500 Pounds of Coal	600 Pounds of Coal	700 Pounds of Coal	800 Pounds of Coal	900 Pounds of Coal	1000 Pounds of Coal	Average Pounds of Coal	
1	2	3	4	5	6	7	8	9	10	11
Group BA-10. With Brick Arch										
Macoupin (Ill.)	4.6	4.3	4.2	4.1	4.1	4.1	4.2	4.4	4.3	100.0
Marion (Ill.)	5.7	5.0	4.6	4.4	4.4	4.6	5.0	5.7	4.9	114.0
Saline (Ill.)	4.7	4.3	4.0	3.8	3.8	3.8	3.9	4.1	4.1	95.3
Sangamon (Ill.)	4.9	4.6	4.3	4.1	3.9	3.9	3.9	4.2	4.2	97.7
Vermillion (Ill.)	4.7	4.3	4.1	4.0	4.0	4.0	4.1	4.3	4.2	97.7
Williamson (Ill.)	4.7	4.4	4.2	3.9	3.8	3.9	4.1	4.5	4.2	97.7
Greene (Ind.)	4.5	4.2	3.9	3.7	3.6	3.5	3.5	3.7	3.8	88.4
Sullivan (Ind.)	5.2	4.6	4.3	4.1	4.1	4.3	4.5	4.8	4.5	104.7
Vermillion (Ind.)	4.6	4.2	4.0	3.8	3.8	3.9	4.0	4.3	4.1	95.3
Vigo (Ind.)	5.0	4.5	4.3	4.1	4.0	4.1	4.2	4.4	4.3	100.0
Averages	4.9	4.4	4.2	4.0	4.0	4.0	4.1	4.4	4.3	100.0
Group NA-4. Without Brick Arch										
Macoupin (Ill.)	4.5	4.5	4.6	4.6	4.6	4.6	4.5	4.4	4.5	97.8
Williamson (Ill.)	4.6	4.3	4.2	4.2	4.3	4.3	4.5	4.6	4.4	95.7
Sullivan (Ind.)	5.4	4.8	4.4	4.3	4.3	4.4	4.7	5.1	4.7	102.2
Vermillion (Ind.)	4.9	4.5	4.3	4.3	4.3	4.5	4.7	5.1	4.6	100.0
Averages	4.9	4.5	4.4	4.4	4.4	4.5	4.6	4.8	4.6	100.0
Group BA-4. With Brick Arch										
Macoupin (Ill.)	4.6	4.3	4.2	4.1	4.1	4.1	4.2	4.4	4.3	100.0
Williamson (Ill.)	4.7	4.4	4.2	3.9	3.8	3.9	4.1	4.5	4.2	97.7
Sullivan (Ind.)	5.2	4.6	4.3	4.1	4.1	4.3	4.5	4.8	4.5	104.7
Vermillion (Ind.)	4.6	4.2	4.0	3.8	3.8	3.9	4.0	4.3	4.1	95.3
Averages	4.8	4.4	4.2	4.0	4.0	4.1	4.2	4.5	4.3	100.0

* "Rating Per Cent" is on the basis of the average for the group.

average. The highest average consumption was 14 per cent more, and the lowest average consumption was 11.6 per cent less, than the general average.

The minimum average quantity of dry coal consumed per dynamometer horse-power-hour was obtained when the rate of power developed was approximately 600 dynamometer horse-power. The amount of coal consumed per unit of power developed was nearly uniform for eight of the coals when developing 1,000 dynamometer horse-power, but there was a very wide variation in results obtained from the other two coals tested, one being much above, and the other much below, the average. Several of the coals produced between 1,100 and 1,250 dynamometer horse-power.

In the determinations made at the various rates of power developed, from 300 to 1,000 dynamometer horse-power, there was a decrease in the average quantity of dry coal consumed per dynamometer horse-power-hour from 4.9 to 4.4 pounds for group BA-10, from 4.9 to 4.8 pounds for group NA-4 and from 4.8 pounds to 4.5 pounds for group BA-4. The decrease in amount of coal consumed per unit of power developed was much greater for the tests in which the fire-box was equipped with the brick arch than for those in which the brick arch was removed.

The average amount of coal consumed per dynamometer horse-power-hour was 4.6 pounds for group NA-4 and 4.3 pounds for group BA-4, a decrease of 0.3 pounds or 6.5 per cent in favor of the brick arch when burning coals of the same kind.

701.51 Density of Visible Smoke Discharges: Observations of the density of the smoke discharges emitted from the locomotive stack were taken at intervals during each test. The readings thus taken for each of the test coals, as set forth by table CDLXXXIII, were plotted and a curve was drawn through the points so located. Values were taken from this curve corresponding to rates of combustion ranging from 30 to 100 pounds of coal per square foot of grate surface per hour, the increase proceeding by increments of ten. Values thus obtained are presented in table CDXCIII.

The average values presented for the different coals in table CDXCIII were averaged and the result thus obtained was taken as a basis upon which the relative density of the visible smoke emitted in the case of each coal tested might be rated.

From the ratings thus established, it appears that as the rate of combustion increased from 30 to 100 pounds of coal per square foot of grate surface per hour, the average smoke density increased from 21.8 per cent to 34.7 per cent for group BA-10, from 31.1 per cent to 49.9 per cent for group NA-4, and from 21.8 per cent to 35.1 per cent for group BA-4. These facts indicate that the presence of the brick arch in the fire-box results in a decrease of 33.2 per cent in the emission of visible smoke from the stack.

By studying the values given in table CDLXXXII and those in table CDXCIII, a relation was established between the volatile matter and fixed carbon in the coal and the density of visible smoke discharges. Within the limits presented by the coals tested, however, it appears that the density of smoke discharges is not affected by the composition of the coal.

701.52 Quantity of Cinders and Fuel Dust Contained in the Smoke Emissions: The quantity of cinders and fuel dust emitted in the smoke discharges was determined for each coal tested and for the various rates of combustion employed with each coal. The values presented by results of the tests were plotted and a curve drawn through the points thus located. Readings were taken from this curve of different rates of combustion, varying from 30 to 100 pounds of coal per square foot of grate surface per hour, the increase proceeding by increments of ten. These values, grouped in the same manner as the results presented in preceding tables, are set forth as table CDXCIV.

The values presented in the last column of table CDXCIV indicate the relative ratings of the several coals based upon the average emission rates of all coals tested. From these values it appears that the amounts of solid matter emitted in the smoke discharges of the several coals varied greatly. The reasons for this wide variation of values for different coals are not apparent. The rate of emission of solids increased in all cases as the rate of combustion increased from 30 to 100 pounds of fuel per square foot of grate surface per hour, this increase being from 3.15 per cent of the fuel fired to 6.94 per cent for group BA-10, from 2.62 per cent to 11.53 per cent for group NA-4 and from 3.72 per cent to 6.34 per cent for group BA-4. The average values for solids emitted in smoke, in all cases in which the rate of combustion was more than 50 pounds of fuel per square foot of grate surface per hour, were less for tests in which the brick arch equipment was used in the fire-box than for tests in which the brick arch was omitted, and the total average values for all rates of combustion show that the brick arch is responsible for a reduction of 24.8 per cent in the amount of solids emitted in smoke.

701.53 Chemical Composition and Calorific Value of the Cinders and Fuel Dust Contained in Smoke Emissions: The samples of solid materials collected during the tests were analyzed to determine their chemical composition and calorific value. Determinations were made for nine of the ten samples of coals when burned in a locomotive equipped with a brick arch in the fire-box and for four coals burned in a locomotive not so equipped. Comparison was made also between three of the coals when burned with and without the brick arch equipment. The results of the analyses are presented, for dry cinders and dust, in table CDXCV and for wet cinders and dust as taken from the cinder arrester, in table CDXCVI. The quantities in these tables were obtained from the results of one test with each of the nine coals burned with the brick arch in the fire-box, and from the results of one test with each of the four coals burned without the brick arch.

From the values presented in tables CDXCV and CDXCVI, it appears that the heat units per pound of dry cinders and fuel dust averaged 546 B. t. u., or 5.7 per cent less with the brick arch than without, for the three coals tested with and without the brick arch.

The average calorific values of the cinders and dust, compared with the average calorific values of the coals, are given in table CDXCVII.

TABLE CDXCIII. SMOKE DENSITIES (RINGELMANN SCALE) EXPRESSED IN PER CENT
(Tests made at Altoona, Pa.)

County of Origin	Pounds of Coal Fired per Square Foot of Grate Surface per Hour									Rating Per Cent*
	30	40	50	60	70	80	90	100	Average	
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	
1	2	3	4	5	6	7	8	9	10	11
Group BA-10. With Brick Arch										
Macoupin (Ill.)	22.0	20.0	20.0	20.5	22.5	26.0	30.5	36.0	24.7	104.7
Marion (Ill.)	25.0	16.5	14.0	14.0	15.0	18.0	22.0	27.5	19.0	80.5
Snline (Ill.)	26.5	24.5	24.5	25.5	30.5	37.0	46.0	56.6	34.0	144.2
Sangamon (Ill.)	19.0	18.0	18.5	20.0	22.0	25.5	29.5	33.5	23.3	98.7
Vermillion (Ill.)	22.0	22.0	22.0	22.0	22.0	22.0	22.5	24.0	22.3	94.5
Willinnison (Ill.)	12.5	13.5	14.5	16.0	18.5	22.0	26.0	31.0	19.3	81.8
Greene (Ind.)	15.0	11.0	10.0	11.0	14.0	19.5	28.0	40.0	18.6	78.8
Sullivan (Ind.)	28.5	27.0	26.5	26.0	26.0	28.0	31.5	38.5	29.0	122.9
Vermillion (Ind.)	24.0	19.0	18.0	18.5	19.5	24.0	29.0	35.0	23.4	99.3
Vigo (Ind.)	23.5	22.5	21.5	21.0	21.0	21.0	22.5	25.0	22.3	94.5
Averages	21.8	19.4	19.0	19.6	21.1	24.3	28.8	34.7	23.6	100.0
Group NA-4. Without Brick Arch										
Macoupin (Ill.)	25.0	26.5	29.0	32.0	35.0	38.0	41.5	45.0	34.0	93.1
Williamson (Ill.)	18.5	20.0	21.0	22.5	24.0	26.0	28.0	31.0	23.9	65.4
Sullivan (Ind.)	44.0	45.0	46.0	48.0	50.0	53.5	60.0	69.5	52.0	142.4
Vermillion (Ind.)	37.0	30.5	28.5	28.5	31.0	36.0	44.0	54.0	36.2	99.1
Averages	31.1	30.5	31.1	32.8	35.0	38.4	43.4	49.9	36.5	100.0
Group BA-4. With Brick Arch										
Macoupin (Ill.)	22.0	20.0	20.0	20.5	22.5	26.0	30.5	36.0	24.7	102.5
Williamson (Ill.)	12.5	13.5	14.5	16.0	18.5	22.0	26.0	31.0	19.3	80.1
Sullivan (Ind.)	28.5	27.0	26.5	26.0	26.0	28.0	31.5	38.5	29.0	120.3
Vermillion (Ind.)	24.0	19.0	18.0	18.5	19.5	24.0	29.0	35.0	23.4	97.1
Averages	21.8	19.9	19.8	20.3	21.6	25.0	29.3	35.1	24.1	100.0

* "Rating Per Cent" is on the basis of the average for the group.

TABLE CDXCIV. CINDERS AND FUEL DUST IN SMOKE EMISSIONS EXPRESSED IN PER CENT OF FUEL FIRED WHEN BURNING COAL AT RATES RANGING FROM 30 TO 100 POUNDS PER SQUARE FOOT OF GRATE SURFACE PER HOUR
(Tests made at Altoona, Pa.)

County of Origin	Pounds of Coal Fired per Square Foot of Grate Surface per Hour									Rating Per Cent*
	30	40	50	60	70	80	90	100	Average	
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	
1	2	3	4	5	6	7	8	9	10	11
Group BA-10. With Brick Arch										
Macoupin (Ill.)	2.55	2.36	2.25	3.29	4.32	5.49	6.60	7.80	4.33	95.0
Marion (Ill.)	2.88	3.42	2.83	3.60	4.62	5.96	7.07	8.30	4.84	106.2
Saline (Ill.)	2.10	1.90	2.70	4.00	4.78	5.22	5.69	6.20	4.07	89.3
Sangamon (Ill.)	2.90	2.32	2.05	2.66	3.18	4.05	4.89	5.75	3.48	76.3
Vermillion (Ill.)	2.56	2.73	3.03	3.70	4.51	5.53	6.56	7.58	4.53	99.3
Williamson (Ill.)	2.85	2.80	2.65	2.20	1.99	2.10	2.20	2.36	2.39	52.4
Greene (Ind.)	3.79	6.95	7.34	6.53	7.62	8.73	9.83	10.91	7.71	169.2
Sullivan (Ind.)	3.06	2.76	2.92	3.73	4.42	5.08	5.70	6.39	4.26	93.4
Vermillion (Ind.)	6.42	4.32	3.45	4.17	4.95	6.21	7.44	8.78	5.72	125.5
Vigo (Ind.)	2.43	3.42	4.29	4.40	4.49	4.75	5.03	5.29	4.26	93.4
Averages	3.15	3.28	3.35	3.82	4.51	5.31	6.10	6.94	4.56	100.0
Group NA-4. Without Brick Arch										
Macoupin (Ill.)	2.38	2.46	2.56	3.22	4.11	5.20	6.55	8.05	4.32	77.7
Williamson (Ill.)	3.01	2.59	2.30	4.04	5.85	7.25	8.10	8.92	5.26	94.6
Sullivan (Ind.)	3.36	2.88	2.69	3.52	4.34	6.48	11.45	16.48	6.40	115.1
Vermillion (Ind.)	1.67	2.51	3.50	4.92	6.30	8.17	10.36	12.66	6.26	112.6
Averages	2.62	2.61	2.76	3.93	5.15	6.78	9.12	11.53	5.56	100.0
Group BA-4. With Brick Arch										
Macoupin (Ill.)	2.55	2.36	2.25	3.29	4.32	5.49	6.60	7.80	4.33	103.7
Williamson (Ill.)	2.85	2.80	2.65	2.20	1.99	2.10	2.20	2.36	2.39	57.2
Sullivan (Ind.)	3.06	2.76	2.92	3.73	4.42	5.08	5.70	6.39	4.26	102.0
Vermillion (Ind.)	6.42	4.32	3.45	4.17	4.95	6.21	7.44	8.78	5.72	137.0
Averages	3.72	3.05	2.82	3.35	3.93	4.73	5.49	6.34	4.18	100.0

* "Rating Per Cent" is on the basis of the average for the group.

TABLE CDXCV. CHEMICAL COMPOSITION AND CALORIFIC VALUE OF DRY CINDERS AND FUEL DUST IN SMOKE EMISSIONS

(Tests made at Altoona, Pa.)

County of Origin	British Thermal Units	Proximate Analysis*			Sulphur Per Cent	Weight in Per Cent of Coal Fired
		Volatile Matter Per Cent	Fixed Carbon Per Cent	Ash Per Cent		
1	2	3	4	5	6	7
Group BA-9—With Brick Arch						
Marion (Ill.)	9803	10.63	61.88	27.49	2.86	6.24
Saline (Ill.)	9156	8.45	60.18	31.37	2.08	4.56
Sangamon (Ill.)	7888	13.36	49.78	36.86	3.57	3.13
Vermillion (Ill.)	8917	11.85	56.01	32.14	2.45	3.90
Williamson (Ill.)	8888	11.92	57.57	30.51	2.00	1.91
Greene (Ind.)	8431	14.70	52.83	32.47	2.53	6.44
Sullivan (Ind.)	8680	10.95	54.82	34.23	2.64	4.21
Vermillion (Ind.)	9624	11.07	61.54	27.39	3.19	3.06
Vigo (Ind.)	9067	13.22	56.61	30.17	3.68	4.50
Averages	8939	11.79	56.80	31.41	2.78	4.22
Group NA-4—Without Brick Arch						
Macoupin (Ill.)	9261	10.19	56.56	33.25	3.20	5.16
Williamson (Ill.)	9817	9.93	58.76	31.31	1.31	6.94
Sullivan (Ind.)	9270	9.19	57.31	33.50	2.43	4.91
Vermillion (Ind.)	9742	8.99	62.57	28.44	3.13	7.09
Averages	9523	9.58	58.80	31.62	2.52	6.03
Group BA-3—With Brick Arch						
Williamson (Ill.)	8888	11.92	57.57	30.51	2.00	1.91
Sullivan (Ind.)	8680	10.95	54.82	34.23	2.64	4.21
Vermillion (Ind.)	9624	11.07	61.54	27.39	3.19	3.06
Averages	9064	11.31	57.98	30.71	2.61	3.06
Group NA-3—Without Brick Arch						
Williamson (Ill.)	9817	9.93	58.76	31.31	1.31	6.94
Sullivan (Ind.)	9270	9.19	57.31	33.50	2.43	4.91
Vermillion (Ind.)	9742	8.99	62.57	28.44	3.13	7.00
Averages	9610	9.37	59.55	31.08	2.29	6.31

* The totals of columns 3, 4 and 5 equal 100 per cent.

TABLE CDXCVI. CHEMICAL COMPOSITION AND CALORIFIC VALUE OF CINDERS AND FUEL DUST IN SMOKE EMISSIONS

(Tests made at Altoona, Pa.)

County of Origin	British Thermal Units	Total Moisture* Per Cent	Proximate Analysis †				Sulphur Per Cent
			Moisture Per Cent	Volatile Matter Per Cent	Fixed Carbon Per Cent	Ash Per Cent	
1	2	3	4	5	6	7	8
Group BA-9—With Brick Arch							
Marion (Ill.)	9242	24.63	5.72	10.02	58.34	25.92	2.70
Saline (Ill.)	8999	5.22	1.72	8.30	59.15	30.83	2.04
Sangamon (Ill.)	7677	4.12	2.67	13.00	48.45	35.88	3.47
Vermillion (Ill.)	8671	22.01	2.76	11.52	54.47	31.25	2.38
Williamson (Ill.)	8588	20.40	3.38	11.52	55.62	29.48	1.93
Greene (Ind.)	8167	4.00	3.13	14.24	51.18	31.45	2.45
Sullivan (Ind.)	8562	1.36	1.36	10.80	54.07	33.77	2.60
Vermillion (Ind.)	9286	7.83	3.51	10.68	59.38	26.43	3.08
Vigo (Ind.)	8907	15.42	1.76	12.99	55.61	29.64	3.62
Averages	8678	11.67	2.89	11.45	55.14	30.52	2.70
Group NA-4—Without Brick Arch							
Macoupin (Ill.)	9049	3.76	2.29	9.96	55.27	32.48	3.13
Williamson (Ill.)	9307	20.47	5.20	9.41	55.71	29.68	1.24
Sullivan (Ind.)	9170	16.13	1.08	9.09	56.69	33.14	2.40
Vermillion (Ind.)	9572	2.64	1.74	8.83	61.48	27.95	3.08
Averages	9275	10.75	2.58	9.32	57.29	30.81	2.46
Group BA-3—With Brick Arch							
Williamson (Ill.)	8588	20.40	3.38	11.52	55.62	29.48	1.93
Sullivan (Ind.)	8562	1.36	1.36	10.80	54.07	33.77	2.60
Vermillion (Ind.)	9286	7.83	3.51	10.68	59.38	26.43	3.08
Averages	8812	9.86	2.75	11.00	56.36	29.89	2.54
Group NA-3—Without Brick Arch							
Williamson (Ill.)	9307	20.47	5.20	9.41	55.71	29.68	1.24
Sullivan (Ind.)	9170	16.13	1.08	9.09	56.69	33.14	2.40
Vermillion (Ind.)	9572	2.64	1.74	8.83	61.48	27.95	3.08
Averages	9350	13.08	2.67	9.11	57.96	30.26	2.24

* As collected in the depository arrester.

† The totals of columns 4, 5, 6 and 7 equal 100 per cent.

TABLE CDXCVII. AVERAGE CALORIFIC VALUES OF CINDERS AND DUST COMPARED WITH THOSE OF COAL

(Tests made at Altoona, Pa.)

Group	Heat Units Contained in the Cinders and Dust Per Pound of Coal Burned B. t. u.	Heat Units Contained in the Coals B. t. u.	Per Cent Loss
1	2	3	4
BA-9	377	11,808	3.19
NA-4	574	11,661	4.92
BA-3	277	11,761	2.36
NA-3	606	11,761	5.16

The heat units rejected in the dry cinders and fuel dust, per pound of coal fired, were equivalent to 3.19 per cent of the calorific value of the coal for group BA-9, to 4.92 per cent for group NA-4, to 2.36 per cent for group BA-3 and to 5.16 per cent for group NA-3. The average values for the three coals tested with and without the brick arch indicate that the heat loss in cinders and fuel dust discharged in the smoke is 54.3 per cent less when the brick arch is used than when it is omitted.

From a comparison of the ratings of the ten coals, in which the average quantity of cinders and fuel dust contained in the smoke emissions is expressed in per cent of the general average for the ten coals, when burning the coals at rates ranging from 30 to 100 pounds per square foot of grate surface per hour, it appears that seven of the coals averaged less than the general average and three averaged more. The highest rate of emission was 69.2 per cent more, and the lowest 47.6 per cent less, than the general average.

From a comparison of equal weights of cinders and dust obtained from burning three of the coals in a fire-box with and without a brick arch, it appears that when burned with brick arch the cinders and dust contain:

Heat units	5.7 per cent less
Volatile matter	20.7 per cent more
Fixed carbon	2.6 per cent less
Sulphur	14.0 per cent more

Determinations were made of the quantities of tar, carbon, ash and sulphur contained in the cinders and fuel dust emitted in smoke at rates of combustion varying from 30 to 100 pounds of coal per square foot of grate surface per hour, the increase in rate proceeding by increments of ten. The test values were plotted in the usual manner and readings were taken from the diagrams thus prepared to correspond to the rates of combustion mentioned. These values for the various samples of coal grouped as in previous presentations are given in tables CDXCVIII to DI, inclusive.

From the values presented in table CDXCVIII it appears that, with the brick arch in the fire-box, the maximum average rate of emission of tar for the ten coals occurred at the lowest rate of combustion, or at 30 pounds per square foot of grate surface per hour, and the minimum average rate of emission occurred when the rate of combustion was about 50 pounds. Without the brick arch, the maximum average rate of emission of tar occurred when the coal was burned at a rate of 70 to 80 pounds per square foot of grate surface per hour, but the average rates of emission of tar were practically uniform for all rates of combustion. The total average rates of emission of tar for the same four coals when burned with and without the brick arch were identical.

From the values presented in table CDXCIX it appears that, with the brick arch in the fire-box, the maximum average rate of emission of carbon for the ten coals occurred at the highest rate of combustion, or at 100 pounds per square foot of grate surface per hour, and the minimum rate of emission of carbon occurred at the lowest rate of combustion, or at 30 pounds. Without the brick arch, the maximum rate of emission of carbon occurred at 100 pounds of coal per square foot of grate surface per hour and the minimum occurred at 30 pounds. The total average rates of emission of carbon for the same four coals were 24 per cent less with the brick arch than without.

From the values presented in table D it appears that, with the brick arch in the fire-box, the maximum average rate of emission of ash for the ten coals occurred at the highest rate of combustion, or at 100 pounds of coal per square foot of grate surface per hour, and the minimum average rate of emission of ash occurred at the lowest rate of combustion, or at 30 pounds. For the four coals burned without the brick arch, the relation between emission rates of combustion was essentially the same. With the same four coals, the total average rate of emission of ash was 27 per cent less with the brick arch than without.

From the values presented in table DI it appears that, with the brick arch in the fire-box, the maximum average rate of emission of sulphur for ten coals occurred at a rate of combustion of 100 pounds of coal per square foot of grate surface per hour, and the minimum rate of emission of sulphur occurred at about 50 pounds. For the four coals tested without the brick arch, the maximum average rate of emission of sulphur occurred at a rate of combustion of 100 pounds of coal per square foot of grate surface per hour, and the minimum at about 40 pounds. For the same four coals, the total average rate of emission of sulphur was 24 per cent less with the brick arch than without.

701.54 Chemical Composition and Calorific Value of Ash and Clinker: The proximate analyses of the ash and clinker which passed through the grate during certain of the tests and the heat value of these discharges were determined both for dry ash and for ash as taken from the pit. The results of these determinations are presented in tables DII and DIII. The quantities in these tables are obtained from the results of one test with each of the nine coals burned with the brick arch in the fire-box, and from the results of one test with each of the four coals burned without brick arch.

For the nine coals tested with the brick arch in the fire-box, the number of heat units contained in the dry ash and clinker, as shown by table DII, ranged from 1,467 to 6,209 B. t. u., and averaged 4,008 B. t. u. per pound of ash and clinker.

For the three coals tested with the brick arch in the fire-box, the number of heat units contained in the dry ash and clinker ranged from 1,467 to 4,184 B. t. u., and averaged 3,273 B. t. u. per pound of ash and clinker. For the same coals tested without the brick arch, the corresponding range was from 3,192 to 4,758 B. t. u., and the average was 4,195 B. t. u. per pound

TABLE CDXCVIII. QUANTITIES OF TAR CONTAINED IN THE CINDERS AND FUEL DUST EMITTED IN SMOKE FROM A LOCOMOTIVE SMOKE-STACK WHEN BURNING COAL AT 30 TO 100 POUNDS PER SQUARE FOOT OF GRATE SURFACE PER HOUR

(Tests made at Altoona, Pa.)

County of Origin	Pounds of Coal Fired per Square Foot of Grate Surface per Hour								
	30	40	50	60	70	80	90	100	Average
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
1	2	3	4	5	6	7	8	9	10
Group BA-10. With Brick Arch									
Macoupin (Ill.)	0.032	0.018	0.006	0.008	0.010	0.011	0.011	0.011	0.013
Marion (Ill.)	0.008	0.011	0.011	0.011	0.013	0.015	0.017	0.020	0.013
Saline (Ill.)	0.012	0.009	0.009	0.010	0.012	0.014	0.016	0.018	0.013
Sangamon (Ill.)	0.020	0.015	0.012	0.014	0.017	0.015	0.012	0.011	0.015
Vermillion (Ill.)	0.022	0.012	0.006	0.009	0.010	0.008	0.007	0.005	0.010
Williamson (Ill.)	0.019	0.009	0.002	0.003	0.003	0.003	0.002	0.002	0.005
Greene (Ind.)	0.012	0.006	0.009	0.018	0.013	0.008	0.004	0.002	0.009
Sullivan (Ind.)	0.038	0.023	0.016	0.021	0.022	0.022	0.022	0.021	0.023
Vermillion (Ind.)	0.086	0.032	0.006	0.016	0.024	0.024	0.025	0.025	0.030
Vigo (Ind.)	0.051	0.027	0.012	0.015	0.017	0.017	0.015	0.014	0.021
Averages	0.030	0.016	0.009	0.013	0.014	0.014	0.013	0.013	0.015
Group NA-4. Without Brick Arch									
Macoupin (Ill.)	0.005	0.003	0.002	0.003	0.006	0.008	0.010	0.013	0.006
Williamson (Ill.)	0.013	0.007	0.002	0.003	0.005	0.006	0.007	0.007	0.006
Sullivan (Ind.)	0.028	0.025	0.022	0.025	0.028	0.027	0.014	0.001	0.021
Vermillion (Ind.)	0.008	0.028	0.048	0.046	0.043	0.043	0.048	0.052	0.040
Averages	0.014	0.016	0.019	0.019	0.021	0.021	0.020	0.018	0.018
Group BA-4. With Brick Arch									
Macoupin (Ill.)	0.032	0.018	0.006	0.008	0.010	0.011	0.011	0.011	0.013
Williamson (Ill.)	0.019	0.009	0.002	0.003	0.003	0.003	0.002	0.002	0.005
Sullivan (Ind.)	0.038	0.023	0.016	0.021	0.022	0.022	0.022	0.021	0.023
Vermillion (Ind.)	0.086	0.032	0.006	0.016	0.024	0.024	0.025	0.025	0.030
Averages	0.044	0.021	0.008	0.012	0.015	0.015	0.015	0.015	0.018

TABLE CDXCIX. QUANTITIES OF CARBON CONTAINED IN THE CINDERS AND FUEL DUST EMITTED IN SMOKE FROM A LOCOMOTIVE SMOKE-STACK WHEN BURNING COAL AT 30 TO 100 POUNDS PER SQUARE FOOT OF GRATE SURFACE PER HOUR

(Tests made at Altoona, Pa.)

County of Origin	Pounds of Coal Fired per Square Foot of Grate Surface per Hour								
	30	40	50	60	70	80	90	100	Average
	Per Cent of Fuel Fired								
1	2	3	4	5	6	7	8	9	10
Group BA-10. With Brick Arch									
Macoupin (Ill.)	1.77	1.51	1.33	2.25	3.14	4.21	5.22	6.33	3.22
Marion (Ill.)	1.84	2.00	1.57	2.30	3.06	4.15	5.01	5.98	3.24
Saline (Ill.)	1.38	1.27	1.91	2.93	3.53	3.91	4.31	4.75	3.00
Sangamon (Ill.)	1.39	1.19	1.14	1.58	1.93	2.72	3.49	4.27	2.21
Vermillion (Ill.)	1.50	1.62	1.87	2.27	2.95	3.91	4.87	5.82	3.10
Williamson (Ill.)	1.90	1.84	1.71	1.35	1.23	1.40	1.57	1.79	1.60
Greene (Ind.)	2.37	4.51	4.80	4.29	5.20	6.12	7.03	7.92	5.28
Sullivan (Ind.)	1.88	1.62	1.76	2.45	2.99	3.46	3.88	4.39	2.80
Vermillion (Ind.)	3.69	2.60	2.20	2.78	3.41	4.42	5.41	6.51	3.88
Vigo (Ind.)	1.32	1.92	2.57	2.79	2.99	3.24	3.53	3.79	2.77
Averages	1.90	2.01	2.09	2.50	3.04	3.75	4.43	5.16	3.11
Group NA-4. Without Brick Arch									
Macoupin (Ill.)	1.51	1.46	1.44	2.00	2.81	3.81	5.04	6.41	3.06
Williamson (Ill.)	1.95	1.77	1.66	2.85	4.11	5.09	5.78	6.43	3.71
Sullivan (Ind.)	1.99	1.71	1.56	2.10	2.63	4.24	7.94	11.72	4.24
Vermillion (Ind.)	0.89	1.40	2.06	3.19	4.26	5.65	7.13	8.68	4.16
Averages	1.59	1.59	1.68	2.54	3.45	4.70	6.47	8.31	3.79
Group BA-4. With Brick Arch									
Macoupin (Ill.)	1.77	1.51	1.33	2.25	3.14	4.21	5.22	6.33	3.22
Williamson (Ill.)	1.90	1.84	1.71	1.35	1.23	1.40	1.57	1.79	1.60
Sullivan (Ind.)	1.88	1.62	1.76	2.45	2.99	3.46	3.88	4.39	2.80
Vermillion (Ind.)	3.69	2.60	2.20	2.78	3.41	4.42	5.41	6.51	3.88
Averages	2.31	1.89	1.75	2.21	2.69	3.37	4.02	4.76	2.88

TABLE D. QUANTITIES OF ASH CONTAINED IN THE CINDERS AND FUEL DUST EMITTED IN LOCOMOTIVE SMOKE WHEN BURNING COAL AT 30 TO 100 POUNDS PER SQUARE FOOT OF GRATE SURFACE PER HOUR

(Tests made at Altoona, Pa.)

County of Origin	Pounds of Coal Fired per Square Foot of Grate Surface per Hour								
	30	40	50	60	70	80	90	100	Average
	Per Cent of Fuel Fired								
1	2	3	4	5	6	7	8	9	10
Group BA-10. With Brick Arch									
Macoupin (Ill.)	0.67	0.76	0.85	0.98	1.12	1.19	1.24	1.28	1.01
Marion (Ill.)	1.02	1.39	1.17	1.15	1.37	1.57	1.75	1.99	1.43
Saline (Ill.)	0.66	0.59	0.74	1.01	1.16	1.21	1.27	1.33	1.00
Sangamon (Ill.)	1.41	1.05	0.84	0.99	1.14	1.23	1.32	1.41	1.17
Vermillion (Ill.)	0.93	1.02	1.14	1.35	1.46	1.51	1.57	1.63	1.33
Williamson (Ill.)	0.87	0.90	0.90	0.81	0.73	0.67	0.60	0.55	0.73
Greene (Ind.)	1.32	2.30	2.39	2.10	2.27	2.45	2.62	2.80	2.28
Sullivan (Ind.)	1.05	1.04	1.07	1.17	1.30	1.48	1.67	1.84	1.21
Vermillion (Ind.)	2.41	1.54	1.14	1.26	1.39	1.62	1.84	2.06	1.66
Vigo (Ind.)	0.97	1.37	1.58	1.45	1.32	1.32	1.31	1.31	1.23
Averages	1.13	1.20	1.18	1.23	1.33	1.43	1.52	1.62	1.33
Group NA-4. Without Brick Arch									
Macoupin (Ill.)	0.81	0.94	1.06	1.14	1.19	1.24	1.32	1.41	1.14
Williamson (Ill.)	0.96	0.75	0.59	1.13	1.67	2.07	2.18	2.30	1.46
Sullivan (Ind.)	1.25	1.07	1.03	1.30	1.57	2.07	3.26	4.42	2.00
Vermillion (Ind.)	0.74	1.02	1.30	1.56	1.83	2.27	2.93	3.63	1.91
Averages	0.94	0.95	1.00	1.28	1.57	1.91	2.42	2.91	1.63
Group BA-4. With Brick Arch									
Macoupin (Ill.)	0.67	0.76	0.85	0.98	1.12	1.19	1.24	1.28	1.01
Williamson (Ill.)	0.87	0.90	0.90	0.81	0.73	0.67	0.60	0.55	0.75
Sullivan (Ind.)	1.05	1.04	1.07	1.17	1.30	1.48	1.67	1.84	1.23
Vermillion (Ind.)	2.41	1.54	1.14	1.26	1.39	1.62	1.84	2.06	1.66
Averages	1.25	1.06	0.99	1.06	1.14	1.24	1.34	1.43	1.19

TABLE DI. QUANTITIES OF SULPHUR CONTAINED IN THE CINDERS AND FUEL DUST EMITTED IN LOCOMOTIVE SMOKE WHEN BURNING COAL AT 30 TO 100 POUNDS PER SQUARE FOOT OF GRATE SURFACE PER HOUR

(Tests made at Altoona, Pa.)

County of Origin	Pounds of Coal Fired per Square Foot of Grate Surface per Hour								
	30	40	50	60	70	80	90	100	Average
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
1	2	3	4	5	6	7	8	9	10
Group BA-10. With Brick Arch									
Macoupin (Ill.)	0.078	0.072	0.064	0.052	0.050	0.079	0.129	0.179	0.088
Marion (Ill.)	0.012	0.019	0.079	0.139	0.177	0.225	0.263	0.310	0.153
Saline (Ill.)	0.048	0.031	0.041	0.050	0.078	0.086	0.094	0.102	0.064
Sangamon (Ill.)	0.080	0.065	0.058	0.076	0.093	0.085	0.068	0.050	0.073
Vermillion (Ill.)	0.108	0.078	0.054	0.071	0.090	0.102	0.113	0.125	0.093
Williamson (Ill.)	0.061	0.051	0.038	0.037	0.027	0.027	0.028	0.018	0.036
Greene (Ind.)	0.088	0.134	0.141	0.122	0.137	0.152	0.176	0.188	0.142
Sullivan (Ind.)	0.092	0.077	0.074	0.089	0.108	0.118	0.128	0.139	0.103
Vermillion (Ind.)	0.234	0.148	0.104	0.114	0.126	0.146	0.163	0.183	0.153
Vigo (Ind.)	0.089	0.103	0.128	0.145	0.163	0.173	0.175	0.176	0.144
Averages	0.089	0.078	0.078	0.090	0.105	0.119	0.134	0.148	0.105
Group NA-4. Without Brick Arch									
Macoupin (Ill.)	0.055	0.057	0.058	0.077	0.104	0.142	0.180	0.217	0.111
Williamson (Ill.)	0.087	0.063	0.048	0.057	0.065	0.084	0.133	0.183	0.090
Sullivan (Ind.)	0.092	0.075	0.078	0.095	0.112	0.143	0.236	0.339	0.146
Vermillion (Ind.)	0.032	0.062	0.092	0.124	0.167	0.207	0.252	0.298	0.154
Averages	0.067	0.064	0.069	0.088	0.112	0.144	0.200	0.259	0.125
Group BA-4. With Brick Arch									
Macoupin (Ill.)	0.078	0.072	0.064	0.052	0.050	0.079	0.129	0.179	0.088
Williamson (Ill.)	0.061	0.051	0.038	0.037	0.027	0.027	0.028	0.018	0.036
Sullivan (Ind.)	0.092	0.077	0.074	0.089	0.108	0.118	0.128	0.139	0.103
Vermillion (Ind.)	0.234	0.148	0.104	0.114	0.126	0.146	0.163	0.183	0.153
Averages	0.116	0.087	0.070	0.073	0.078	0.093	0.113	0.130	0.095

TABLE DII. CHEMICAL COMPOSITION AND CALORIFIC VALUE OF DRY ASH AND CLINKER PASSED THROUGH THE GRATE

(Tests made at Altoona, Pa.)

County of Origin	British Thermal Units	Proximate Analysis*			Sulphur Per Cent	Weight of Ash and Clinker in Per Cent of Coal Fired
		Volatile Matter Per Cent	Fixed Carbon Per Cent	Ash Per Cent		
1	2	3	4	5	6	7
Group BA-9. With Brick Arch						
Marion (Ill.)	5521	7.76	34.82	57.42	2.83	19.98
Saline (Ill.)	4208	4.86	29.55	65.59	1.55	8.64
Sangamon (Ill.)	3077	7.99	17.25	74.76	1.85	12.40
Vermillion (Ill.)	4457	6.80	28.99	64.21	1.65	15.02
Williamson (Ill.)	1467	5.62	13.90	80.48	0.48	11.58
Greene (Ind.)	6209	12.34	32.83	54.83	1.73	14.26
Sullivan (Ind.)	4168	4.27	28.38	67.35	2.35	15.03
Vermillion (Ind.)	4184	9.24	24.02	66.74	3.17	19.06
Vigo (Ind.)	2779	7.33	17.18	75.49	1.72	15.49
Averages	4008	7.36	25.22	67.42	1.92	14.61
Group NA-4. Without Brick Arch						
Macoupin (Ill.)	4080	8.17	24.82	67.01	3.91	10.84
Williamson (Ill.)	4758	8.14	26.37	65.49	0.52	12.29
Sullivan (Ind.)	3192	5.89	25.10	69.01	2.24	13.89
Vermillion (Ind.)	4634	6.88	30.38	62.74	3.30	18.73
Averages	4166	7.27	26.67	66.06	2.49	13.94
Group BA-3. With Brick Arch						
Williamson (Ill.)	1467	5.62	13.90	80.48	0.48	11.58
Sullivan (Ind.)	4168	4.27	28.38	67.35	2.35	15.03
Vermillion (Ind.)	4184	9.24	24.02	66.74	3.17	19.06
Averages	3273	6.38	22.10	71.52	2.00	15.22
Group NA-3. Without Brick Arch						
Williamson (Ill.)	4758	8.14	26.37	65.49	0.52	12.29
Sullivan (Ind.)	3192	5.89	25.10	69.01	2.24	13.89
Vermillion (Ind.)	4634	6.88	30.38	62.74	3.30	18.73
Averages	4195	6.97	27.28	65.75	2.02	14.97

* The totals of columns 3, 4 and 5 equal 100 per cent.

TABLE DIII. CHEMICAL COMPOSITION AND CALORIFIC VALUE OF ASH AND CLINKER PASSED THROUGH THE GRATE AS DELIVERED TO THE LABORATORY

(Tests made at Altoona, Pa.)

County of Origin	British Thermal Units	Total Moisture*	Proximate Analysis†				Sulphur Per Cent
			Moisture Per Cent	Volatile Matter Per Cent	Fixed Carbon Per Cent	Ash Per Cent	
1	2	3	4	5	6	7	8
Group BA-9. With Brick Arch							
Marion (Ill.)	5430	26.29	1.65	7.63	34.24	56.48	2.78
Saline (Ill.)	4180	22.10	0.67	4.83	29.35	65.15	1.54
Sangamon (Ill.)	3048	4.24	0.95	7.91	17.09	74.05	1.83
Vermillion (Ill.)	4385	24.26	1.62	6.69	28.52	63.17	1.62
Williamson (Ill.)	1457	15.76	0.69	5.58	13.81	79.92	0.48
Greene (Ind.)	6041	23.01	2.71	12.01	31.94	53.34	1.68
Sullivan (Ind.)	4105	14.51	1.50	4.21	27.96	66.33	2.32
Vermillion (Ind.)	4121	22.19	1.51	9.10	23.66	65.73	3.12
Vigo (Ind.)	2748	15.83	1.10	7.25	16.99	74.66	1.70
Averages	3946	18.69	1.38	7.24	24.84	66.54	1.90
Group NA-4. Without Brick Arch							
Macoupin (Ill.)	4040	27.21	0.97	8.09	24.58	66.36	3.87
Williamson (Ill.)	4651	27.53	2.24	7.96	25.78	64.02	0.51
Sullivan (Ind.)	3170	17.74	0.70	5.85	24.92	68.53	2.22
Vermillion (Ind.)	4578	9.28	1.20	6.80	30.01	61.99	3.26
Averages	4110	20.44	1.28	7.18	26.32	65.22	2.47
Group BA-3. With Brick Arch							
Williamson (Ill.)	1457	15.76	0.69	5.58	13.81	79.92	0.48
Sullivan (Ind.)	4105	14.51	1.50	4.21	27.96	66.33	2.32
Vermillion (Ind.)	4121	22.19	1.51	9.10	23.66	65.73	3.12
Averages	3228	17.49	1.23	6.30	21.81	70.66	1.97
Group NA-3. Without Brick Arch							
Williamson (Ill.)	4651	27.53	2.24	7.96	25.78	64.02	0.51
Sullivan (Ind.)	3170	17.74	0.70	5.85	24.92	68.53	2.22
Vermillion (Ind.)	4578	9.28	1.20	6.80	30.01	61.99	3.26
Averages	4133	18.18	1.38	6.87	26.90	64.85	2.00

* Total moisture in the ash and clinker as taken from the ash-pit below the grate.

† Air dried samples. The totals of columns 4, 5, 6 and 7 equal 100 per cent.

For the nine coals tested with the brick arch, the average calorific value of the coals was 11,808 B. t. u. per pound, and the ash and clinker that passed through the grate contained an average of 586 B. t. u. for each pound of fuel fired, or 4.96 per cent of the calorific value of the fuel.

For the three coals tested with the brick arch, the average calorific value of the coals was 11,761 B. t. u. per pound, and the ash and clinker that passed through the grate contained an average of 498 B. t. u. for each pound of fuel fired, or 4.23 per cent of the calorific value of the coal. For the same three coals tested without the brick arch, the ash and clinker that passed through the grate contained an average of 628 B. t. u. for each pound of fuel fired, or 5.34 per cent of the calorific value of the coal.

The average number of heat units rejected in the ash and clinker were 20.7 per cent less for coals burned with the brick arch than for the same coals when burned without the brick arch.

For the nine coals burned with the brick arch, the volatile matter in the ash and clinker varied from 4.27 to 12.34 per cent and averaged 7.36 per cent of the weight of the ash and clinker.

For the three coals burned with the brick arch, the volatile matter varied from 4.27 to 9.24 per cent and averaged 6.38 per cent of the weight of the ash and clinker. For the same three coals burned without the brick arch, the corresponding range was from 5.89 to 8.14 per cent and the average was 6.97 per cent of the weight of the ash and clinker.

The average content of volatile matter in the ash and clinker discharges from coals when burned with the brick arch was 8.5 per cent less than that contained in such discharges from the same coals when burned without the brick arch.

For the nine coals burned with the brick arch, the fixed carbon contained in the ash and clinker varied from 17.18 to 34.82 per cent, the average being 25.22 per cent of the weight of the dry ash and clinker.

For the three coals burned with the brick arch, the fixed carbon contained in the ash and clinker varied from 13.90 to 28.38 per cent, the average being 22.1 per cent of the weight of the clinker and ash. For the same coals burned without the brick arch, the range of values was from 25.10 to 30.38 per cent, the average being 27.28 per cent of the weight of the clinker and ash. The fixed carbon contained in the ash and clinker discharges from coals burned with the brick arch was 19 per cent less than that contained in such discharges from the same coals when burned without the brick arch.

For the nine coals burned with the brick arch, the sulphur in the ash and clinker discharges varied from 0.48 to 3.17 per cent, the average being 1.92 per cent of the weight of the ash and clinker.

For the three coals burned with the brick arch, the sulphur contained in the ash and clinker discharges varied from 0.48 to 3.17 per cent, the average being 2.0 per cent. For the same coals burned without the brick arch, the range of values was from 0.52 to 3.3 per cent, the average being 2.02 per cent. The sulphur contained in the ash and clinker discharges from coals burned with the brick arch was 1.0 per cent less than that contained in such discharges from the same coals when burned without the brick arch.

Based upon the data contained in table DII, it appears that the use of the brick arch in the fire-box results in fuel economy in that it serves to diminish the loss of heat units through the grate. This is made evident by the following summary:

1. The presence of the brick arch decreases the average number of heat units rejected in the ash and clinker from 5.34 to 4.23 per cent of the heat units in the fuel fired.
2. The presence of the brick arch is responsible for a decrease in the average amount of volatile matter contained in the ash and clinker discharges from 6.97 to 6.38 per cent of the dry ash and clinker.
3. The presence of the brick arch decreases the average amount of fixed carbon rejected in the ash and clinker from 27.28 to 22.10 per cent of the dry ash and clinker.
4. The presence of the brick arch decreases the average amount of sulphur contained in the ash and clinker discharges from 2.02 to 2.00 per cent of the dry ash and clinker.

701.55 Gaseous Constituents of Smoke: The gases emitted in smoke account for a large part of the fuel burned. The weight of the components of fuel which combine with oxygen to form these gases varies from 47.8 to 69.4 per cent of the total weight of fuel burned. Values for the relative volume of the different gases emitted in smoke at different rates of combustion varying from 30 to 100 pounds of coal per square foot of grate surface per hour, as taken from curves prepared in the usual manner from the results of the tests, are presented as table DIV.

The values for oxygen shown in the table represent the oxygen in that portion of the air in the smoke which did not take any part in the process of combustion.

The results obtained when burning the test coals with a brick arch in the fire-box, as compared with those obtained from the same coals without the brick arch, show that the presence of the brick arch results in:

1. A decrease in the volume of the air intermingled with the total volume of gases emitted from 26.5 to 22.5 per cent of the total volume of gases emitted.
2. An increase in the volume of carbon dioxid from 12.0 to 12.7 per cent of the total volume of gases emitted.
3. A decrease in the volume of carbon monoxid from 1.1 to 1.0 per cent of the total volume of gases emitted.
4. A decrease in the volume of oxygen from 5.3 to 4.5 per cent of the total volume of gases emitted.
5. An increase in the volume of sulphur trioxid from 0.0418 to 0.0629 per cent of the total volume of gases emitted.
6. An increase in the volume of sulphur dioxid from 0.0196 to 0.0377 per cent of the total volume of gases emitted.

TABLE DIV. SUMMARY OF ANALYSES (BY VOLUME) OF GASES CONTAINED IN THE DISCHARGE FROM A LOCOMOTIVE SMOKE-STACK

(Tests made at Altoona, Pa.)

County of Origin	Kind of Gas and Per Cent of Total (By Volume)							
	Carbon Dioxid	Carbon Monoxid	Oxygen	Nitrogen	Sulphur Trioxid	Sulphur Dioxid	Total	Air Per Cent*
1	2	3	4	5	6	7	8	9
Group BA-10. With Brick Arch								
Macoupin, (Ill.)	13.9	1.4	2.8	81.9000	†	†	100	14.0
Marion, (Ill.)	12.2	1.3	3.2	83.2364	0.0402	0.0234	100	16.0
Saline, (Ill.)	12.3	1.8	3.4	82.4317	0.0372	0.0311	100	17.0
Sangamon, (Ill.)	12.2	0.2	5.9	81.5445	0.0671	0.0884	100	29.5
Vermillion, (Ill.)	12.5	1.2	4.2	82.0447	0.0370	0.0183	100	21.0
Williamson, (Ill.)	14.0	1.8	2.9	81.2875	0.0110	0.0015	100	14.5
Greene, (Ind.)	11.6	0.5	6.8	80.9990	0.0439	0.0571	100	34.0
Sullivan, (Ind.)	11.6	0.7	5.6	81.9778	0.0760	0.0462	100	28.0
Vermillion, (Ind.)	11.3	0.2	6.7	81.6331	0.1016	0.0653	100	33.5
Vigo, (Ind.)	10.5	0.1	7.4	81.8353	0.0620	0.1027	100	37.0
Averages	12.2	0.9	4.9	81.8989	0.0529	0.0482	100	24.5
Group NA-4. Without Brick Arch								
Macoupin, (Ill.)	12.7	0.8	5.0	81.5000	†	†	100	25.0
Williamson, (Ill.)	12.9	0.9	4.5	81.6880	0.0104	0.0016	100	22.5
Sullivan, (Ind.)	11.5	0.7	5.7	82.0445	0.0381	0.0174	100	28.5
Vermillion, (Ind.)	10.8	1.7	6.1	81.2833	0.0768	0.0399	100	30.5
Averages	12.0	1.1	5.3	81.5386	0.0418	0.0196	100	26.5
Group BA-4. With Brick Arch								
Macoupin, (Ill.)	13.9	1.4	2.8	81.9000	†	†	100	14.0
Williamson, (Ill.)	14.0	1.8	2.9	81.2875	0.0110	0.0015	100	14.5
Sullivan, (Ind.)	11.6	0.7	5.6	81.9778	0.0760	0.0462	100	28.0
Vermillion, (Ind.)	11.3	0.2	6.7	81.6331	0.1016	0.0653	100	33.5
Averages	12.7	1.0	4.5	81.6994	0.0629	0.0377	100	22.5

* In per cent of the total gases emitted.
† Not determined.

TABLE DV. COMPARISON OF RESULTS OBTAINED WITH EXPERIENCED AND WITH INEXPERIENCED FIREMEN OPERATING LOCOMOTIVE AT 80 REVOLUTIONS PER MINUTE AND AT 25.6 PER CENT CUT-OFF, AND BURNING COAL BOTH WITH AND WITHOUT THE BRICK ARCH IN THE FIRE-BOX

(Tests made at Altoona, Pa.)

County of Origin	Pounds of Dry Fuel Fired per Sq. Foot of Grate Surface per Hour	Equivalent Evaporation from and at 212° F. Lb.		Boiler Horse-Power (34.5 U of E.)	Efficiency of Boiler Based on Fuel Per Cent	Dry Fuel per Dynamometer H. P. Hr. Lb.	Thermal Efficiency of Loco. Based on Fuel Per Cent	Average Smoke Density Per Cent	Cinders and Fuel Dust in Per Cent of Fuel as Fired
		Per Sq. Foot of Heating Surface per Hour	Per Lb. of Dry Fuel						
1	2	3	4	5	6	7	8	9	10
Group BA-9. Experienced Firemen—With Brick Arch									
Marion, (Ill.)	47.6	6.7	8.8	657.7	68.3	4.4	4.6	14	3.82
Saline, (Ill.)	43.4	7.1	10.4	702.6	72.3	3.7	4.9	24	1.84
Sangamon, (Ill.)	47.7	7.0	9.3	694.7	71.8	3.9	5.2	18	1.92
Vermillion, (Ill.)	47.0	7.1	9.6	704.4	74.3	4.0	5.1	22	2.88
Williamson, (Ill.)	47.3	7.5	10.1	743.7	76.5	3.9	5.1	14	2.74
Greene, (Ind.)	43.3	7.2	10.5	712.6	78.3	3.6	5.5	8	7.89
Sullivan, (Ind.)	46.0	7.0	9.6	686.8	69.9	4.1	4.7	28	2.61
Vermillion, (Ind.)	45.8	7.2	9.9	709.7	75.5	3.8	5.3	16	3.06
Vigo, (Ind.)	46.8	7.0	9.5	691.4	71.6	4.0	5.0	20	4.21
Averages	46.1	7.1	9.7	700.4	73.2	3.9	5.0	18	3.44
Group BA-9. Inexperienced Firemen—With Brick Arch									
Marion, (Ill.)	63.3	6.3	6.3	618.8	48.4	6.4	3.2	30	2.68
Saline, (Ill.)	64.3	7.6	7.5	749.1	52.1	5.4	3.4	64	4.10
Sangamon, (Ill.)	46.7	5.8	7.8	567.0	59.8	6.0	3.4	52	3.76
Vermillion, (Ill.)	60.7	7.9	8.2	775.3	63.2	5.1	4.0	34	2.26
Williamson, (Ill.)	53.7	7.6	9.0	754.1	68.4	4.4	4.5	16	4.12
Greene, (Ind.)	53.0	7.2	8.6	710.5	63.8	4.6	4.3	26	5.38
Sullivan, (Ind.)	67.8	7.6	7.1	746.5	51.5	5.8	3.3	52	2.71
Vermillion, (Ind.)	56.2	7.5	8.4	739.2	64.1	4.5	4.4	28	5.37
Vigo, (Ind.)	51.7	7.2	8.8	709.0	66.4	4.3	4.7	22	5.66
Averages	57.5	7.2	8.0	707.7	59.7	5.2	3.9	36	4.00
Group NA-2. Experienced Firemen—Without Brick Arch									
Macoupin, (Ill.)	53.7	6.9	8.1	678.8	62.0	4.4	4.6	30	2.56
Williamson, (Ill.)	49.2	7.0	9.0	690.6	68.3	4.2	4.8	24	2.18
Averages	51.5	7.0	8.6	684.7	65.2	4.3	4.7	27	2.37
Group NA-2. Inexperienced Firemen—Without Brick Arch									
Macoupin, (Ill.)	63.6	6.8	6.7	699.9	51.5	5.4	3.7	42	2.57
Williamson, (Ill.)	47.6	7.3	9.7	722.1	73.9	3.8	5.2	20	3.39
Averages	55.6	7.1	8.2	711.0	62.7	4.6	4.5	31	2.98

The carbon dioxid and carbon monoxid contained in the gases are, of course, formed by the combination of oxygen with the carbon contained in the fuel, carbon dioxid being the product of complete combustion and carbon monoxid being the result of incomplete combustion. The carbon contained in these gaseous compounds represents all the carbon in the coal burned, except that contained in the cinders and fuel dust of the smoke discharges and in the ash and clinker discharged through the grate. An average of the values for the carbon compounds at the different rates of combustion indicates that the percentage of carbon monoxid increases, and that of carbon dioxid decreases, as the rate of combustion increases from 30 to 100 pounds of coal per square foot of grate surface per hour. The total quantity of carbon contained in the two gaseous compounds remains practically constant in its relation to the quantity of fuel fired, regardless of the rate of combustion.

The results of the tests show that the quantity of sulphur contained in the coal controls the quantity of the gaseous compounds of sulphur emitted in the smoke, the method of burning the coal and the rate of combustion being apparently factors of little importance.

The results obtained when burning the test coals with a brick arch in the fire-box, as compared with those obtained when burning the same coals without the brick arch, show that the presence of the brick arch results in:

1. An increase in the quantity of carbon as carbon dioxid from 51.1 to 53.2 per cent of the weight of the fuel fired.
2. A decrease in the quantity of carbon as carbon monoxid from 4.3 to 3.8 per cent of the weight of the fuel fired.
3. An increase in sulphur as sulphur trioxid from 0.494 to 0.793 per cent of the weight of the fuel fired.
4. An increase in sulphur as sulphur dioxid, from 0.218 to 0.466 per cent of the weight of the fuel fired.

701.56 Importance of Correct Methods of Firing: A comparison of the results obtained with experienced firemen and those obtained with inexperienced firemen, with the locomotive running at 80 revolutions per minute and with the engine operating at 25.6 per cent cut-off, is presented as table DV.

The values presented by table DV when burning the same kinds of coal in a locomotive fire-box equipped with a brick arch, show that firing by inexperienced firemen, as compared with that by experienced firemen, results in the following:

1. An increase in fuel consumption from 46.1 to 57.5 pounds of fuel fired per square foot of grate surface per hour.
2. An increase in boiler horse-power from 700.4 to 707.7.
3. A decrease in boiler efficiency from 73.2 to 59.7 per cent.
4. An increase in fuel consumed per dynamometer horse-power from 3.9 to 5.2 pounds.
5. An increase in smoke density from 18 to 36 per cent.
6. An increase in cinders and fuel dust discharged in smoke from 3.44 to 4.00 per cent of the fuel fired.
7. A decrease in thermal efficiency from 5.0 to 3.9 per cent.

A similar comparison of the values obtained when firing the same kinds of coal in a locomotive fire-box not equipped with a brick arch shows that firing by inexperienced firemen results in the following:

1. An increase in fuel consumption from 51.5 to 55.6 pounds of fuel fired per square foot of grate surface per hour.
2. An increase in boiler horse-power from 684.7 to 711.0.
3. A decrease in boiler efficiency from 65.2 to 62.7 per cent.
4. An increase in fuel consumed per dynamometer horse-power from 4.3 to 4.6 pounds.
5. An increase in smoke density from 27 to 31 per cent.
6. An increase in cinders and fuel dust discharged in smoke from 2.37 to 2.98 per cent of the fuel fired.
7. A decrease in thermal efficiency from 4.7 to 4.5 per cent.

701.57 The Value of the Brick Arch in the Locomotive Fire-Box: The results obtained from tests conducted with a brick arch in the locomotive fire-box, when compared with those of tests in which the brick arch was omitted, indicate generally that the presence of the brick arch promotes efficiency, decreases losses and reduces smoke. The definite effects have been set forth in the preceding sections. A summary of these facts shows the following results from the presence of the brick arch in the fire-box.

1. Increases the number of pounds of water evaporated per pound of coal from 8.6 to 9.2.
2. Increases the boiler efficiency from 63.4 to 67.8 per cent.
3. Decreases the amount of coal consumed per dynamometer horse-power-hour from 4.6 to 4.3 pounds. This is equivalent to a reduction of 6.5 per cent in the fuel required to maintain a given rate of power delivered at the draw bar.
4. Decreases the average density of visible smoke emissions from 36.5 to 24.1 per cent.
5. Decreases the total average quantity of cinders and fuel dust emitted in smoke from 5.56 to 4.18 per cent of the fuel fired.
6. Decreases the number of heat units per pound of cinders and fuel dust emitted in smoke, from 9,610 to 9,064, increases the amount of volatile matter from 9.37 to 11.31 per cent, decreases the amount of fixed carbon from 59.55 to 57.98 per cent, and increases the amount of sulphur from 2.29 to 2.61 per cent based on the weight of the cinders and fuel dust.
7. Decreases the amount of carbon contained in cinders and fuel dust per ton of coal consumed from 75.8 to 57.6 pounds, decreases the amount of ash from 32.6 to 23.8 pounds, and decreases the amount of sulphur from 2.5 to 1.9 pounds. It shows no effect upon the amount of

tar contained in the cinders and fuel dust emitted in smoke per ton of fuel fired.

8. Decreases the number of heat units contained in the ash and clinker discharges per pound of fuel fired from 628 to 498.

9. Decreases the amount of volatile matter per pound of ash and clinker from 6.97 to 6.38 per cent, decreases the amount of fixed carbon from 27.28 to 22.10 per cent, and decreases the amount of sulphur from 2.02 to 2.00 per cent.

10. Decreases the volume of air intermingled with the gases of combustion discharged through the stack from 26.5 to 22.5 per cent, increases the volume of carbon dioxid discharged through the stack from 12.0 to 12.7 per cent, decreases the volume of carbon monoxid from 1.1 to 1.0 per cent, decreases the volume of oxygen from 5.3 to 4.5 per cent, increases the volume of sulphur trioxid from 0.0418 to 0.0629 per cent and increases the volume of sulphur dioxid from 0.0196 to 0.0377 per cent.

11. Increases that proportion of the carbon in the fuel which combines with oxygen to make carbon dioxid from 51.1 to 53.2 per cent, decreases that proportion which makes carbon monoxid from 4.3 to 3.8 per cent, increases that proportion of the sulphur in the fuel which combines with oxygen to make sulphur trioxid from 0.494 to 0.793 per cent, and increases that proportion which makes sulphur dioxid from 0.218 to 0.446 per cent.

701.58 Conclusions: The facts presented in the preceding sections of this chapter justify the following conclusions:

1. The coals used in the tests conducted in the locomotive laboratory of the Pennsylvania Railroad at Altoona, Pa., do not differ materially from each other in composition or in heating value. As the record indicates, certain of the test coals excelled in respect to one or more of the different measures of performance, but no one sample may be selected as excelling in all respects.

2. The use of incorrect methods of firing, as indicated by the results of tests in which inexperienced firemen were employed, reduces efficiency, increases fuel consumption and fuel losses, and increases smoke discharges.

3. The presence of the brick arch in the locomotive fire-box increases efficiency, decreases fuel consumption, decreases the loss of heat units in the smoke and ash discharges, and reduces the visible smoke.

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INDEX

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